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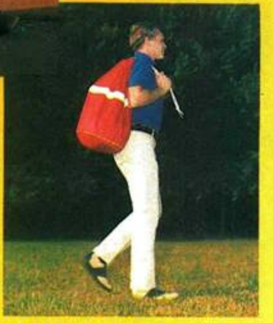

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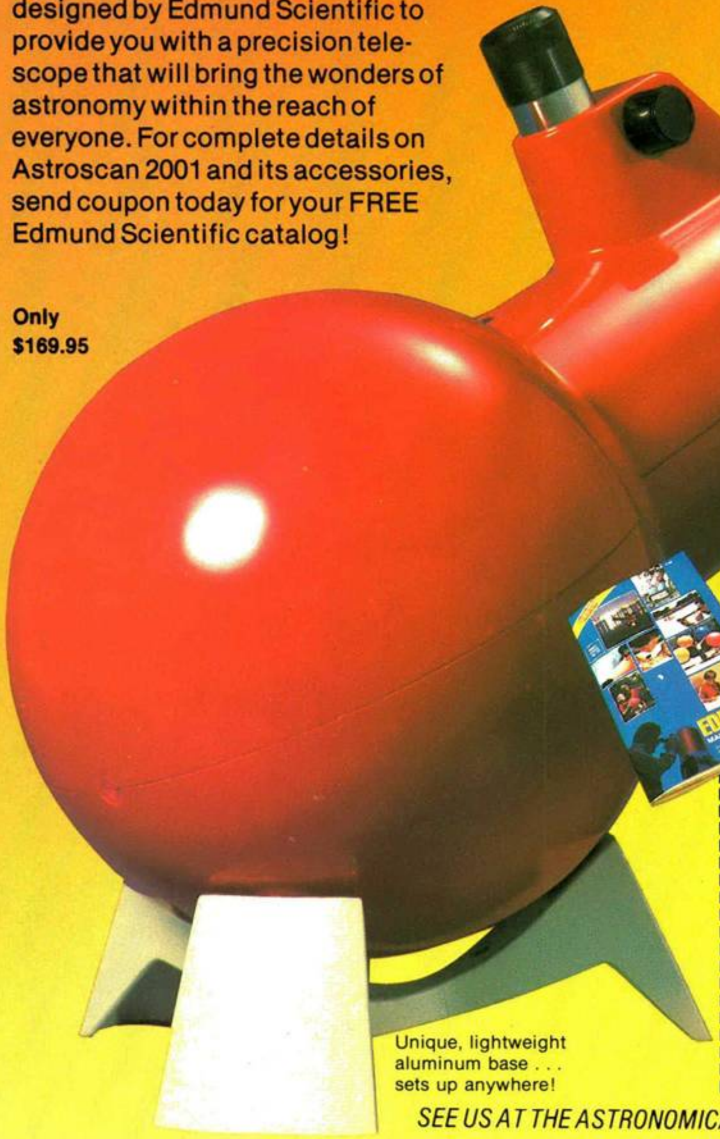

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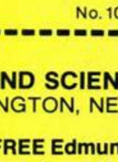

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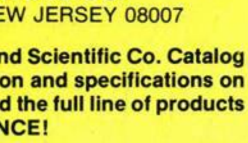

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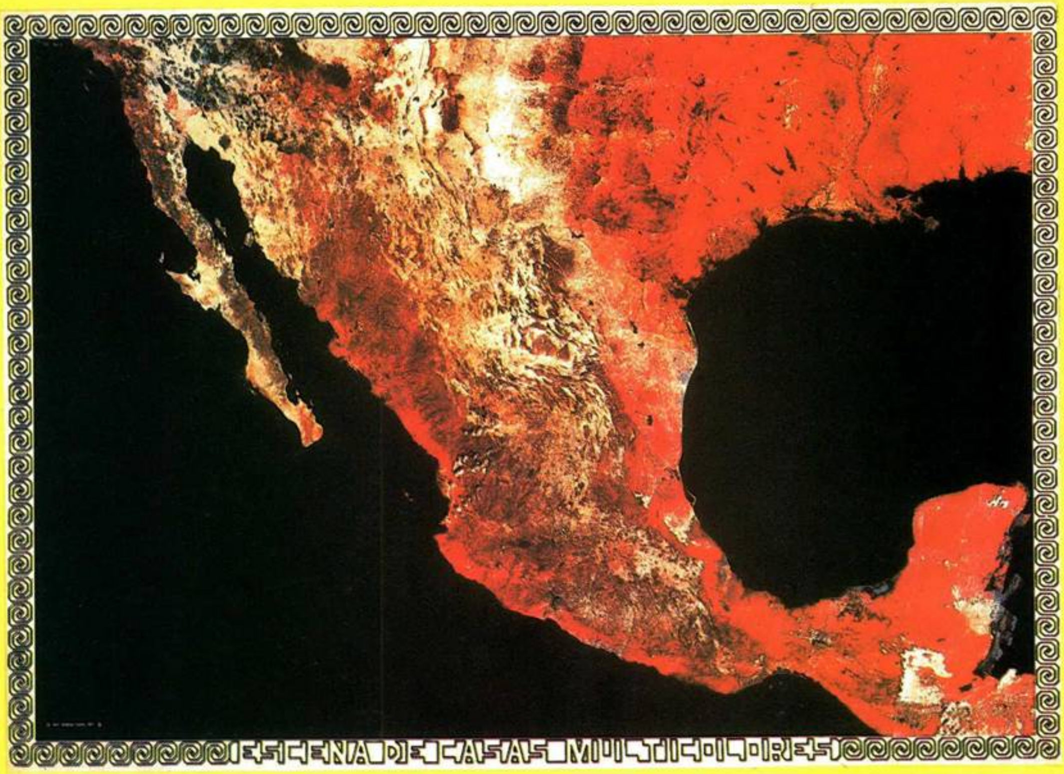

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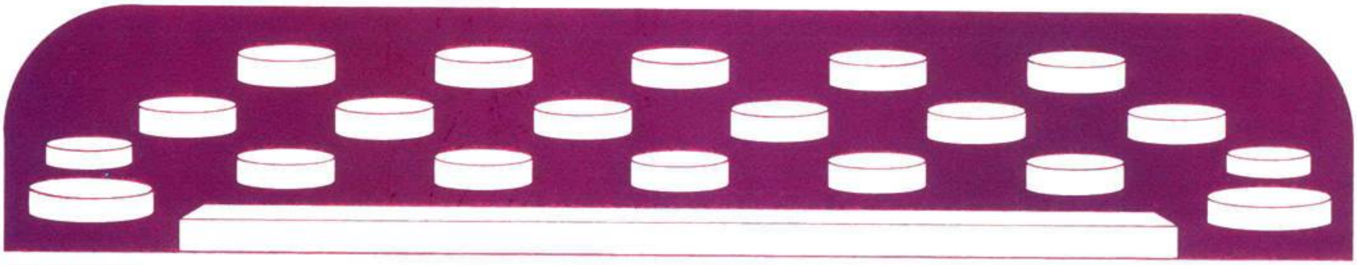

IN FOCUS

Sir / It recently occurred to me after reading your February issue that you might be interested in reports from people who observed the great July sunspot with the naked eye. When I wrote **Naked i Astronomy** I did not include a section about sunspots because I had never seen one without a telescope and I didn't think I ever would.

On July 12 I was in Hastings, England with a group of graduate students on the field trip for my "Astronomy of England" course. We had been to the Herstmonceux Royal Observatory prior to this stop.

Each student had been given the assignment of finding something new during the two week trip. "New" was defined as something astronomical in England that I hadn't seen or didn't know about. One of the course participants, Professor B.G. Tatum of Delta State University in Mississippi, asked if a sunspot would count as something new. There was a very heavy sea mist that day and at 7:00 p.m. it was possible to look momentarily at the Sun without discomfort. A huge sunspot was quite noticeable. I was astonished. I had read about naked–eye sunspots but had never expected to see one. It extended an estimated 1/50 the diameter of the Sun. Unfortunately, no one in the group had a camera lens that was able to record the event.

On the following day, near London's Victoria Station, at around 8:00 p.m., I was again able to observe the sunspot. This time it appeared to have moved closer to the center of the Sun. This and the holding of Isaac Newton's original reflecting telescope were the highlights of the trip.

Prof. George Reed
West Chester State College
West Chester, PA

Sir / I'm very pleased with my first issue of ASTRONOMY. The photography is excellent and the articles are easy to read and understand. In fact, this first issue has rekindled my interest in astronomy as a serious hobby.

One of my interests is radio astronomy. Radio astronomy may not be within your magazine's realm, but if it is, I'd like to buy copies of some recent issues containing articles about radio astronomy — and especially about the Very Large Array (in New Mexico), if you have covered it. Please advise on the availability and cost.

Si Dunn
Dallas, TX

Mr. Dunn / Thank you for your compliments! With regard to your query, radio astronomy is certainly within ASTRONOMY's realm, and we do our best to cover the latest developments. The VLA was discussed in the article, "Radio Interferometry: Stretching Radio Telescope Performance", October 1976, and again in "The Revolution in Astronomy", November 1977. (You might also be interested in the article "Radar Astronomy", December 1976.) Both of these issues are still available at $2.50 each (see the Guide to Back Issues). We will be running other articles on this exciting and growing field in the future; be sure to watch "Astro-News" for recent developments. We hope you continue to enjoy the magazine!

Sir / On the morning of Saturday, April 21, 1979 at 02:33:30 EST, while observing at the Villanova University Observatory, an extremely bright fireball of approximately magnitude -10 was seen. The fireball was a dazzling blue-white and was observed descending from the southeast to the southwest passing about 3° below Spica (Alpha Virginis). A fizzing noise was associated with the fireball. It cast a definite shadow as it passed through the atmosphere and a greenish trail persisted for about four seconds. We would appreciate any communication from any other observer who might have seen this remarkable object.

Michael S. Davis
Joseph L. Fragola
Dept. of Astronomy
Villanova University
Villanova, PA 19085

Sir / On April 22nd, three of my friends and I witnessed an unusual and spectacular sight. We were looking at Jupiter through our telescope when suddenly the sky lit up behind us. The light was intense and looked as though someone had lit a flare. The ground became plainly visible and we saw our shadows in front of us. We all turned around to see what was going on and saw a fireball streaking low across the horizon heading from north-east to north-west. The time was 9:15 p.m. EDT. The fireball was surrounded by an orange glow and disappeared about 3-4 seconds after we turned to look at it. What amazed me was how bright it was — bright enough to enable us to see the twigs on the ground and to cast shadows.

I called the astronomy department at Brown University in nearby Providence, Rhode Island, the next day and it turned out we had seen part of a meteor shower, the Lyrids. How unusual is it to see an astronomical event like this one?

Kathy C. Smith
Greenville, RI

Ms. Smith / Really bright fireballs are rather rare though not as rare as you might think. Guy Ottewell, in his **Astronomical Calendar**, *mentions the existence of an "April fireball" shower lasting over the second half of April, some of which may land as meteorites. It appears that you, Davis, and Fragola observed two of these.*

Sir / While reading your article on the Moon in the June 1979 issue of ASTRONOMY, I was reminded of a letter sent to you some time ago. The gentleman was complaining about difficulty in reading portions of articles that were printed over pictures. I remember thinking at the time that there was somewhat of a problem but that he had exaggerated to some extent.

While studying your photos of the Moon, I was straining to read the labeling. Then I remembered the solution to the problem which I discovered by accident a few months ago. I had been reading in the living room under an incandescent lamp. By putting your magazine under a fluorescent lamp, I found the labeling on the moon photos pratically jumped out of the page. That led me to the conclusion that, like practically all offices, yours used fluorescent lamps and your proofreaders had never had any difficulty reading the final copy.

Warren K. Small
Hooksett, NH

Mr. Small / It wasn't so much the office fluorescents as a desire not to let the legends take over the illustrations. We'd searched the files for some of the best lunar photos we had, and having found them, didn't want to overwhelm them with obtrusive labels. Well, we underwhelmed ... our apologies.

ASTRONOMY

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Cover: Plunging inward, comets of the type known as "sun-grazers" pass closer to the Sun than any other solar system object. After blazing for a few weeks or days, they recede as quickly as they came, returning to the chilly depths of space. In a more cosmological vein, this month ASTRONOMY peeks into a brief but incredibly eventful era — the first second of the universe's existence. Barry Parker's tour takes you through a strange world populated by exotic bits of matter dancing to the tune of the four fundamental forces. And to restore your human perspective, this month we hope to get you looking up at the fine late-summer skies. Comet West photo by Robert Provin.

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The First Second of Time

by Barry Parker

In the first tiny fraction of a second after the Big Bang, our universe was a very different place. The density and temperature were so high that the center of the Sun by comparison is a cold vacuum. Massive, highly-energetic particles — now rare — were common, taking part in exotic reactions against a background of unbelievably intense radiation. Matter and energy were so interchangeable that they could hardly be described as separate entities. Even the forces of nature may have been subsumed under a single primeval force of incredible strength which dominated the very structure of space-time and led to far-reaching consequences. While much has been learned, thanks to recent advances in theoretical physics, about what took place during this brief, strange era, much of what must have happened remains mysterious. Yet the present structure and character of the universe was in large part determined by the events of that time. Painting by Mark Paternostro.

Just try to picture the following: everything that we see around us, out to the farthest limits of the largest telescopes — the whole universe — is crushed and packed into a volume smaller than that of an atom. Then suddenly an explosion of unimaginable intensity takes place and everything is thrown outwards at velocities approaching that of light. The universe is born in a single violent instant of unbelievable chaos. This explosive beginning is called, appropriately enough, the Big Bang.

What was it like? Certainly there's no way we could ever really visualize it — that's beyond our powers of imagination. But we can piece together the events that occurred to get an idea of what happened, for example, in the first second after the Big Bang.

Let's begin by imagining ourselves able to travel backwards in time to this first second. Our universe is still expanding as a result of the Bang; if time is reversed, it will seem to contract. As (immortal) inhabitants of such an imaginary collapsing universe, billions of years will have to pass before we notice much of a difference between a collapse and an expansion. Astronomers will notice a distinction right away, however — the spectral lines of distant galaxies will be shifted toward the blue end of the spectrum instead of being red-shifted.

Eventually, though, the sky will begin to brighten as the background temperature of the universe increases. At first it will hardly be noticeable, but little by little the heat and light will increase until finally conditions are unbearable. What is now only invisible microwave radiation, much longer in wavelength than visible light, will finally become visible and the dark sky will begin to glow with the deepest red imaginable. Gradually this ruddy gleam will become more yellow and then blue-white as the whole sky blazes forth light like the surface of a star.

The universal rise in temperature will long before have made all life impossible. A million or so years after the end of life, the atmospheres of planets and stars alike will boil off into space. Atoms will break up into nuclei and electrons, and then the nuclei themselves will burst apart, leaving only their constituent particles. Finally, the entire universe will consist of nothing but elementary particles and radiation — a dense, unbelievably hot, primordial soup.

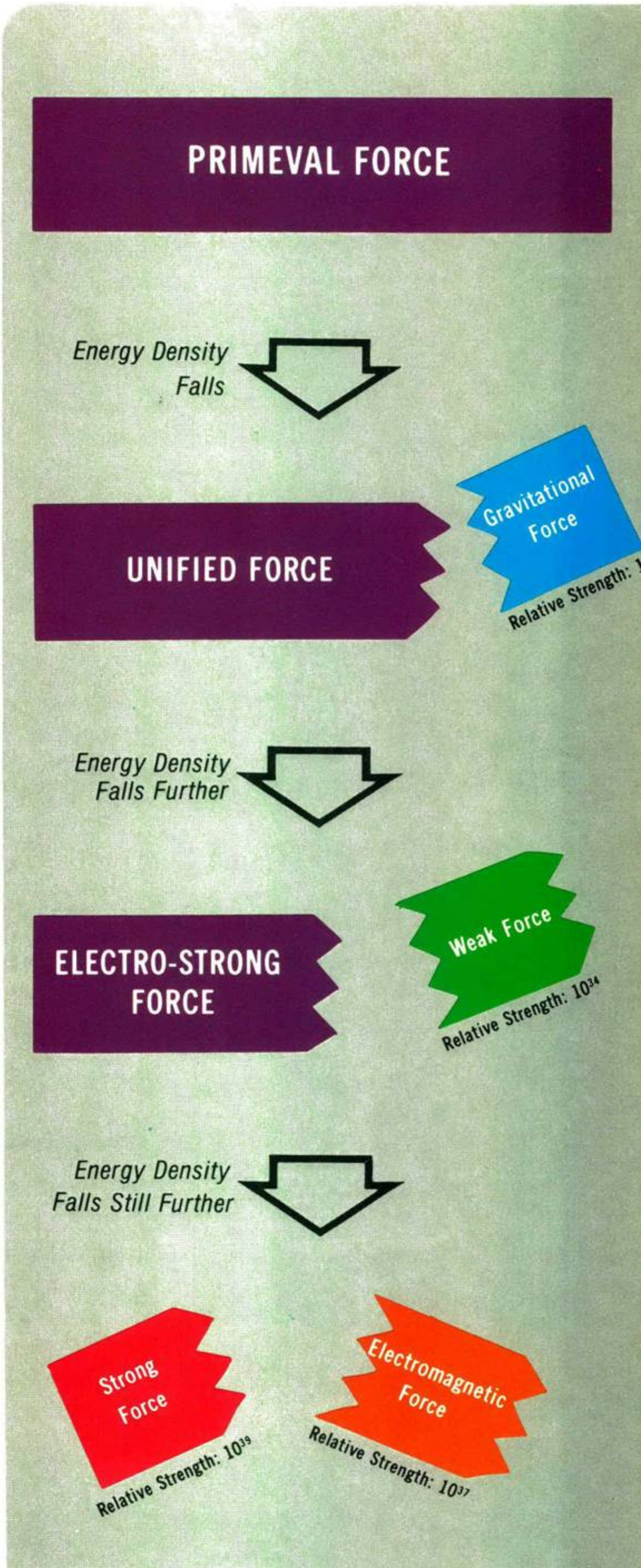
A few black holes may also be present at this stage. As compression continues, many of them will collide and combine. But in the end black holes, particles, and radiation will all finally coalesce into a cosmic nucleus, tiny but all-surpassingly massive.

Now we return to our own expanding universe and ask: what was this cosmic nucleus like? What, for example, was its density? When the Big Bang theory was originally formulated, it was believed that this primordial nucleus consisted mostly of neutrons and therefore had a density of perhaps 10^{14} grams per cubic centimeter — one hundred trillion times as dense as water. We now know, however, that it was likely much more dense than that. Actually, the density of the cosmic nucleus may in fact have been infinite in the beginning, at $t = 0$. We don't know for certain.

What we want to know here, though, is what happened in that first second just after the Big Bang. It might seem strange that we can do this. After all, the Big Bang occurred between 15 and 20 billion years ago and the universe is completely different now. Fortunately, recent advances in physics, particularly in elementary particle physics, have made this possible. In reconstructing the very earliest events, we are not dealing with stars or galaxies; instead we have to deal mainly with elementary particles and the forces between them. Let's begin then with a discussion of these forces.

There are four basic forces of nature. Everyone is quite familiar with at least one of them. The *gravitational force* is the most familiar; it is the force that holds the Moon in orbit and, of course, also holds us to the surface of the Earth. It might seem like a relatively strong force, but it's actually quite weak, much weaker for example than the force that holds the electrons in orbit around the nucleus, namely the *electromagnetic force*. But there are two other forces much stronger than the gravitational: the *weak nuclear force* and, mightiest of all, the *strong nuclear force*.

Let's take a few moments to consider this last force. Perhaps the best way to do this is to perform a simple thought-experiment. Suppose we have two protons. If we bring these particles close together, they repel one another. This is due to the electromagnetic force. The two protons have like charges, and like charges repel one another. If, however, we can somehow overcome this repulsion and get the two particles extremely close together (10^{-13} cms), they will suddenly be overcome by a tremendous attraction. This attraction is due to the strong nuclear force. It is 100 times as strong as the



The four fundamental forces we observe in the universe today may be in reality the fractured parts of what was originally a single primeval force.

electromagnetic force, but behaves quite differently: it has an extremely short range and vanishes at distances even as tiny as the width of an atom.

The last of our four forces — the weak nuclear force — doesn't hold nuclei together in the way the strong nuclear force does, but it is important in other nuclear processes, such as radioactive decay. Nigel Calder calls it the "starbreaker" force because it seems to explain the explosion of some stars. It is also a short range force, and is about a thousand times weaker than the electromagnetic force, yet still enormously stronger than the gravitational force.

These then are the four basic forces of nature. As far as we know, they are the only ones; they differ significantly in strength, character, and range, but each plays an important role in the universe. But why are there exactly four of these forces? Why not five or six? Or, more logically perhaps, why not just one? This is an important question we will come back to later, after we first take a look at what we know about the elementary particles.

No doubt you've heard of the more common, garden-variety ones such as the electron, the proton, and the neutron. But they are only a few of what now amounts to a relatively large "zoo," including a number of neutrinos, several types of mesons, and a considerable number of strange heavy particles called baryons. And, to top this off, each of these has an antiparticle, effectively doubling the total number of particles. When you bring a particle and an antiparticle together, of course, they annihilate one another with the release of a considerable amount of energy.

As particle after particle was discovered, scientists became concerned. Was there any end? At first they merely grouped them into classes. The heaviest were called *hadrons*, the lightest, *leptons*. (Within the hadrons we have the baryons and mesons as sub-classes.) But as the number of these so-called "elementary" particles approached 300, many scientists began to wonder if they were truly elementary after all. Perhaps they were made up of even more fundamental particles.

In the early 1960s a comprehensive theory was proposed. Murray Gell-Mann and George Zweig of Caltech independently suggested that the hadrons were made up of particles which Gell-Mann called *quarks*. There were three of these quarks: the *up*, the *down*, and the *strange* quark, and each had an antiparticle. All hadrons were composed of various combinations of these quarks — the proton, for example, was composed of two ups and a down quark. The theory seemed to be a major breakthrough. Simple recipes involving only a few ingredients could be worked out for all the hadrons, both baryons and mesons. But there was a problem: no one could find a single, isolated quark. Indeed, despite intensive searching they still haven't been found. Of course, that doesn't

While it may be possible to imagine a universe containing matter but without forces of any sort, such a universe would be a most uninteresting one. The particles of matter wouldn't be able to interact with each other in any way whatever, so no building-up of more complex entities would be possible and nothing would ever "happen." Every particle would remain static — isolated, eternally alone, and unchanging.

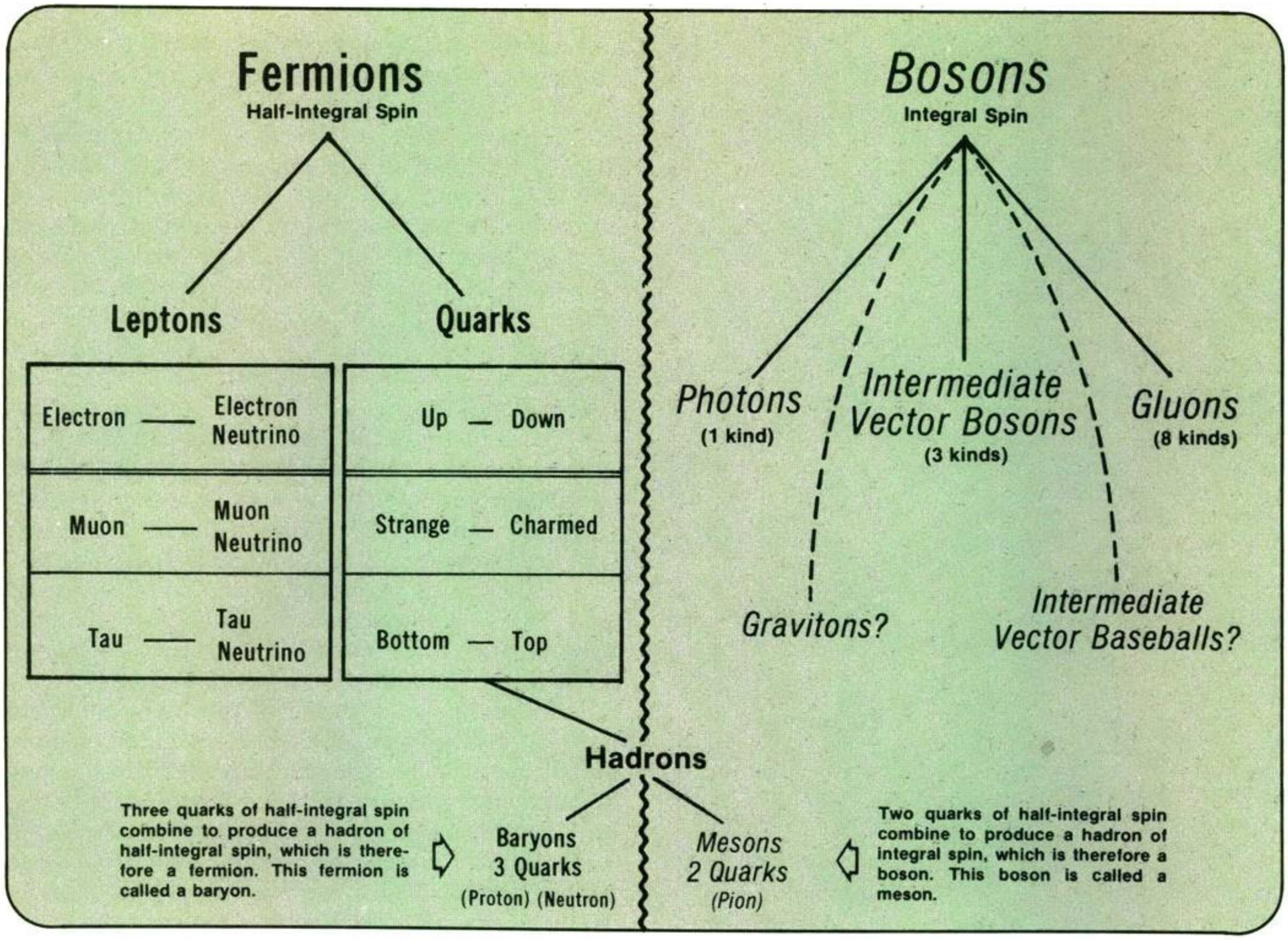
Fortunately our universe isn't like that. There are at least four forces operating in the universe: the *gravitational*, the *weak*, the *electromagnetic*, and the *strong*. These forces differ in a number of ways, but especially in relative strength and range. The gravitational and electromagnetic forces, for example, are long-range forces that can operate over cosmic distances, but the weak and strong forces are significant only at subatomic distances.

The relative strengths of the four forces vary enormously. The strong force, mightiest of all, is about 100 times as powerful as the more familiar electromagnetic, but since, as we mentioned above, it functions only over extremely short distances, its strength is "confined." The weak force, also a short-range force, is about a thousand times weaker than the electromagnetic and therefore a hundred thousand times weaker than the strong. It governs certain types of radioactive decay.

The gravitational force is in some ways the most mysterious of them all. By far the weakest of all forces — only 0.000000000000000000000000000000000000001 (10^{-39}) as powerful as the strong force — it is the one which literally holds the universe together. This happens for two reasons: first, the gravitational force, unlike the other forces, operates on *all* particles, regardless of their charge or makeup; second, it is only an attractive force — unlike electromagnetism, the other long-range force, in which like charges repel and unlike attract. This means that the gravitational force can build up to an enormous strength when enough particles of matter are brought together, such as in the Earth or Sun. Of course there is far, far more electromagnetic force in bodies that size, but it is almost all neutralized by the fact that ordinary matter is composed about equally of positive and negative charges. There is no such thing as "negative" gravity, though.

Scientists hope that eventually a single mathematical structure will be found which can describe all four forces as manifestations of an underlying unity — a *Unified Field Theory*. It seems that as the energy of particle interactions increases, the strengths of the forces change, the weak force, for example, becoming stronger while the strong force weakens. At a sufficiently high energy — far, far greater than can be reached in any way today — all the forces of nature may have the same strength. At that point they would be indistinguishable from each other — becoming, in fact, a single force.

Such energies may have been common during the first tiny fraction of a second after the Big Bang. Thus, it may be that in the beginning, the universe knew only a single force, which because of the rapid subsequent cooling and expansion, lost a great deal of energy and "fractured" into the four forces we observe today. Modern physics may be able to reconstruct the nature of that primeval force by extrapolating backwards from what we know of the mathematical structure of the four forces today, and such a primeval force would be the same thing as the force described by a Unified Field Theory. The problems involved in the unification of forces, however, while apparently not insurmountable, are truly staggering in their magnitude.


Fermions
Half-Integral Spin
Leptons
Quarks
Electron — Electron Neutrino
Muon — Muon Neutrino
Tau — Tau Neutrino
Up — Down
Strange — Charmed
Bottom — Top
Bosons
Integral Spin
Photons (1 kind)
Intermediate Vector Bosons (3 kinds)
Gluons (8 kinds)
Gravitons?
Intermediate Vector Baseballs?
Hadrons
Three quarks of half-integral spin combine to produce a hadron of half-integral spin, which is therefore a fermion. This fermion is called a baryon.
Baryons 3 Quarks (Proton) (Neutron)
Mesons 2 Quarks (Pion)
Two quarks of half-integral spin combine to produce a hadron of integral spin, which is therefore a boson. This boson is called a meson.

The fundamental building blocks of the universe as now known are depicted schematically above. Fermions constitute the "matter" of the universe while bosons provide binding forces to hold particles together. Anti-particles have been omitted. For more information, see box opposite.

necessarily mean they don't exist, and in fact physicists are now studying some theories that assert "free quarks" can't, even in principle, be isolated and identified. We'll just have to wait and see.

Anyway, with this brief introduction to elementary particles as the main actors in our drama, we're ready to look at the earliest beginnings of the universe. The first question that comes to mind is: how far back can we look? In other words, what is the shortest time after the explosion itself, after time zero, that we can talk about with any confidence? The answer may surprise you — it's considerably less than a second, perhaps 1/100 second. But scientists are human like everybody else, and they naturally like to speculate on what was going on even before this. Of course, it's not *pure* speculation by any means — it's just that they're on rather shaky ground when they start looking before 1/100 second.

Is there any kind of limit as we go back further and further? Indeed there is. The best way to understand it is to consider *how* we look back. We use a theory, which in this case is Einstein's General Theory of Relativity. Where, we ask, does this theory break down? It turns out that it is valid up to an unbelievably high density of about 10^{94} gms/cm^3, calculated to occur at 10^{-43} seconds after time zero. Our limit, then, is t = 0.000000000000000000000000000000000000000001 second! Before this point in time modern science can tell us nothing.

We'll begin then at 10^{-43} seconds after the Bang. Let's consider the four basic forces of nature first. What were they like at this time? Of course we're not certain, but an interesting theory has recently been proposed. According to this theory, these forces may have been of equal strength at this time. In other words, there may have been only one unified force. If true, this gives us some insight into a question we asked earlier: why are there four forces of nature instead of just one? Now we can answer: in the beginning there may actually have been only one.

Gradually, however, the unity of the single primordial force was shattered by the expansion of the universe and the forces we now know broke away and separated into four distinct forces. One could think of them as phases "condensing out," so to speak, as the universe cooled, just as ice condenses out as water cools. The first to separate out was gravity (shortly after 10^{-43} seconds), and it soon became much weaker than the others.

At 10^{-23} seconds the universe entered what

How to Build a Universe

Suppose you decide, some rainy day, to build your very own universe. What would you need? Well, you would have to have some kind of material with which to construct it. It would probably be a more interesting universe, though, if you used several different kinds of material — such as wood, metal, cloth, and plastic. Then you would also need something to hold your material together. Since you're using different materials, you'll have to have several different kinds of "connectors" — like nails for the wood, solder for the metal, thread for the cloth, and glue for the plastic. Some of these connectors, of course, should be usable with more than one material, such as a glue for wood and cloth as well as plastic, so that the different materials can be connected to each other as well as to themselves.

It turns out that the real universe is very like this home-workshop project. It is constructed out of two fundamentally different kinds of things, material parts and connectors for those parts. The material parts are particles called *fermions*, while the connectors are known as *bosons*. (The two are distinguished technically by the value of their quantum mechanical "intrinsic spin" — integral, such as 0 or 1, for the bosons, and half-integral, such as 1/2 or 3/2, for the fermions.)

First let's look at the fermions, the building blocks of the universe. Just as you can make a more interesting model universe by using more than one kind of material, our universe is made of two fundamentally different kinds of fermions: *leptons* and *quarks*. Both are believed to be truly elemental, that is, with no internal structure whatsoever, the ultimate "bits" of which the universe is made.

The class of fermions known as leptons is the most familiar, for it includes the *electron*, famous in TV sets around the world. There are other leptons, however, whose names are not really household words, such as the *muon* (a sort of heavy electron) and the *tau* (an even heavier member of the class only recently detected). Each of these three leptons is paired with one of three more leptons called *neutrinos*: the *electron neutrino*, the *muon neutrino*, and the *tau neutrino*. And finally, each of these six leptons has an anti-particle twin, so there are six anti-leptons as well.

One of the most fascinating things to come out of modern physics in recent years is the discovery that there is an apparent symmetry between the leptons and the quarks. Just as there are six leptons paired off into three pairs, there seem to be six quarks paired off into three pairs. The first pair is made up of the *up* quark and the *down* quark, the second pair is the *strange* quark and the *charmed* quark, and the third the *bottom* quark and the *top* quark. (The last two, most recently postulated, are sometimes said to have the qualities of "beauty" and "truth" instead of bottomness and topness. In any case, the names are all whimsical, given only to distinguish, not to define.) The quarks though, unlike the leptons, never appear in isolation but are always combined in various ways to make *hadrons*, a class which includes the familiar protons and neutrons. If three quarks are combined to make a hadron, it is called a *baryon* (both the proton and the neutron are baryons), and a combination of two quarks makes a hadron known as a *meson*.

Interestingly enough, it seems that our own universe could have been constructed wholly out of just one pair of leptons — the electron and the neutrino — and one pair of quarks — up and down (which combine to make neutrons and protons). The other two pairs in each class appear only in high energy physics, never in everyday matter, and seem to be altogether superfluous. One of the mysteries of modern physics is why there are all these "extra" particles, particles which may be, in a very profound sense, unnecessary. It is as though you set out to construct a miniature model wooden ship, and bought a ton of sheet metal just in case. The answer may lie in processes which took place only in the first second of time, when such exotic particles were common.

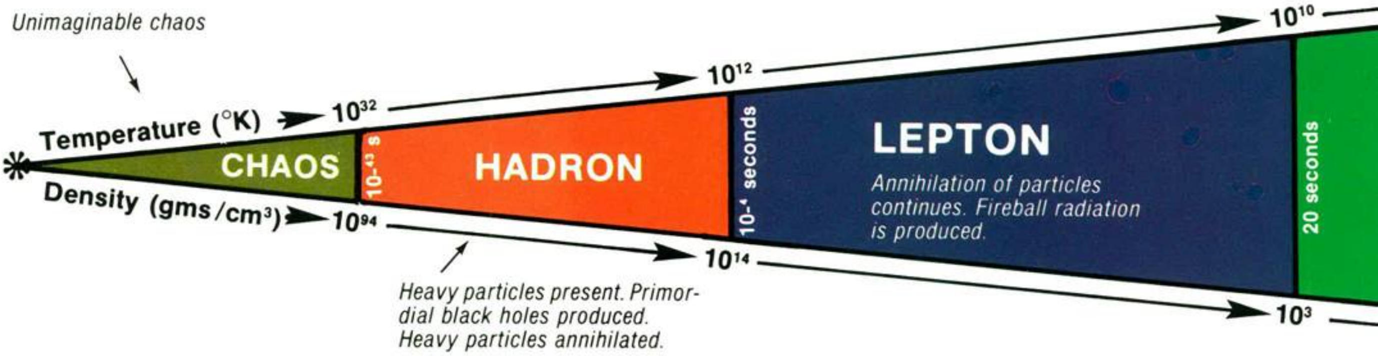
What about the boson "connectors," used to hold the fermions of the universe together? Again we find there are several different kinds, which operate on different fermions in different ways to connect them to each other. These bosons correspond to the four forces of nature (see box on p. 9). There is just one boson which carries, or "mediates", the electromagnetic force: the *photon*. Three bosons, known as the *intermediate vector* bosons, mediate the weak force and act as connectors between certain fermions. The strong force requires a total of eight bosons, called *gluons* in direct recognition of their connective "glue" role in binding together quarks. (Since the gravitational force has not yet been accounted for by a quantum mechanical theory like the other three, it is not known how many "gravitons" carry this force.)

The connectors can do more than just bind together different particles. They can also change one kind of fermion into another. An intermediate vector boson, for example, can change a muon into an electron. Viewed in four dimensional space-time, though, this can be seen as just another kind of binding — one which binds across time rather than space. Thus it can be said that the intermediate vector boson acts as a glue between the past muon and the future electron. One problem is that there doesn't seem to be any "glue" which can bind together in a time sense the two separate families of leptons and quarks (photons, which bind electrons and protons across space, won't work that way across time). In other words, there is no way to change a lepton into a quark, or vice versa.

But because of the beautiful symmetry between quarks and leptons, theorists are very suspicious that something connects these two fundamental classes of fermions. That something, it turns out, would be a fifth basic force of nature, which theorists have dubbed the hyperweak force. Like the other forces, the hyperweak would be mediated by a class of bosons acting as connectors between particles. Calculations indicate that the masses of these bosons would be enormous — far greater than the masses of any particles so far observed or even theorized. Because of their enormous mass, theorists have taken to calling them *intermediate vector baseballs* (though they don't actually have anywhere near the mass of a baseball).

In a number of ways, these super-heavy particles could help explain just how our universe was constructed out of the chaos of the first second. The baseballs would represent a unification of forces, for their energy is about at the level at which the strength of the strong, electromagnetic, and weak forces is the same. They could also help account for why there is so much more matter than anti-matter in the universe.

One very interesting thing the intermediate vector baseballs could still do (if they exist) is cause the decay of protons, otherwise thought to be stable with infinite lifetimes, into less massive leptons. This could lead to the eventual breakdown of matter in the universe, since protons are one of the fundamental building blocks of atoms.



According to modern cosmology, the early evolution of the universe was marked by a succession of distinctive "eras" as diagramed above. The very earliest moments — before 10^{-43} seconds — are still shrouded in mystery. Following a period when the four forces of nature first began to separate out of a single primeval force, the universe entered the Hadron Era. This was followed by the Lepton, Radiation, and finally the Matter Eras. Because of the enormous range in duration, time is not shown to a uniform scale.

scientists call the *Hadron Era*. Two different models have been suggested for this era. One is referred to as the *elementary particle model*, while the other is called the *composite particle model*.

The elementary particle model (the more conventional of the two) is frequently called the "hot" Big Bang model because of the extremely high temperatures allowed in it. A crude estimate places the universe at about 10^{32} Kelvins just before it entered the Hadron Era. According to this model, hadrons are indeed composed of quarks, but at this early point in the history of the universe they had not yet become organized into "hadron packages." Therefore the universe at this time consisted of leptons and quarks together with their antiparticles, and photons (the quanta of radiation).

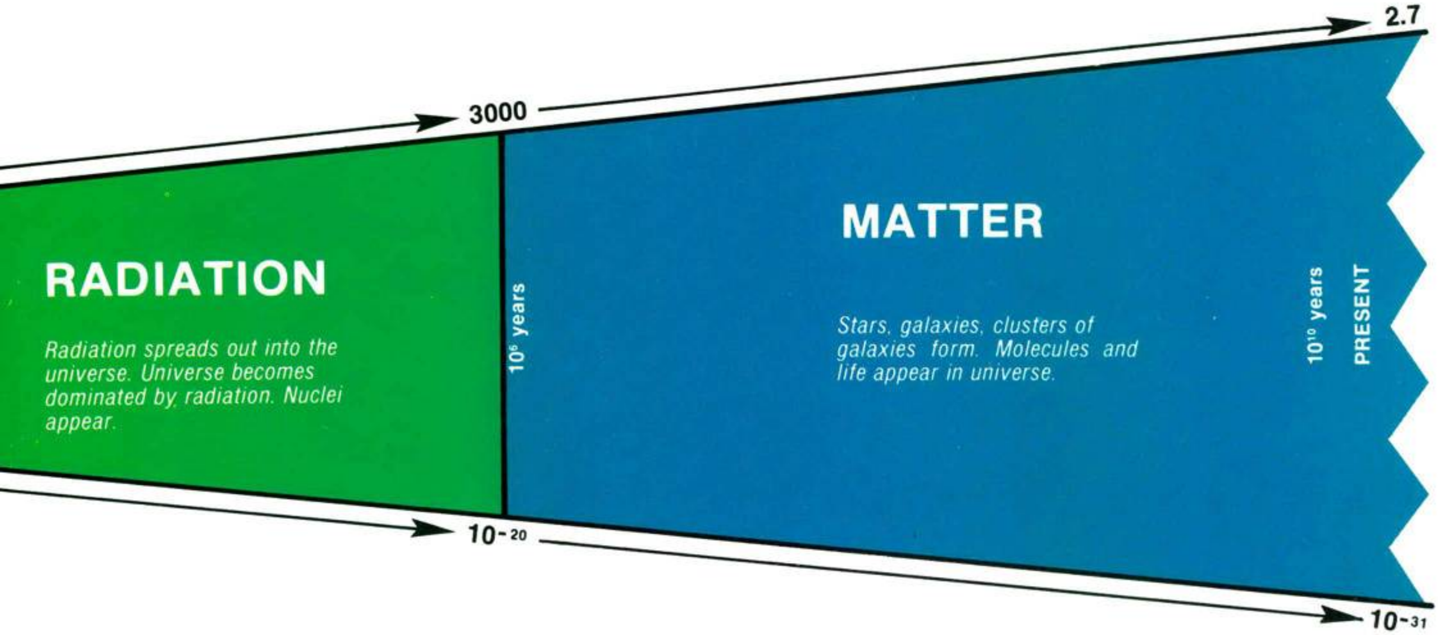
Unfortunately, there's a flaw in this theory. If quarks were indeed running around unconfined at that time, there should be some remnant of them left now. In fact, the Russian theorist Ya. B. Zeldovich has shown that they should be about as common as gold atoms. But, as we mentioned earlier, not even one free quark has ever been found. Why? We don't know. The answer may lie in the still-hidden secret of quark confinement — or perhaps quarks just don't exist at all.

Let's turn now to the composite particle model. In this model we assume there are no true elementary particles. Instead of the fundamental leptons and quarks, this theory sees the sub-atomic particles as resonant energy states of each other, rather like harmonic overtones on a nuclear keyboard. R. Hagedorn of CERN laboratories in Geneva has suggested a particularly interesting theory of this type. He bases his ideas on recent experimental evidence in high energy physics. One of the important consequences of his theory is a limiting, or maximum, temperature of approximately 10^{12} K (about one trillion degrees). This is obviously much lower than that allowed in the elementary particle model, and as a result it is usually thought of as the "warm" Big Bang model.

And, as you might expect, there is also a "cold" Big Bang model, proposed in 1968 by D. Layzer. This theory differs in an important respect from the other two: no antimatter was present during the initial stages of the explosion. In general, this theory has not met with much success.

According to the more accepted ideas, temperatures were high during the Hadron Era and both particles and antiparticles were present. Furthermore, there may have been another important phenomenon associated with this era: the production of primordial black holes. Some of these black holes would have been tiny, hardly larger than an atom, while others would have been gigantic, perhaps as massive as a galaxy. They would have been produced by inhomogeneities in the Big Bang. If, for example, pockets of matter lagged as expansion occurred around them, they would have been compressed into black holes. In fact, it may well be that a considerable fraction of the matter that expanded out in the Big Bang explosion was compressed into black holes. If this were the case, we obviously have to add black holes to our list of components of the Hadron Era.

With both black holes and quarks present at this time it is tempting to go back to a problem we kicked around earlier: why haven't we found any free quarks? C.J. Isham, Abdus Salam, and J. Strandthdee have given an interesting answer to this. They suggest that quarks might be confined inside tiny black holes. Remember: black holes have a one-way membrane — the *event horizon*.


2.7
3000
MATTER
RADIATION
Radiation spreads out into the universe. Universe becomes dominated by radiation. Nuclei appear.
10^6 years
Stars, galaxies, clusters of galaxies form. Molecules and life appear in universe.
10^{10} years
PRESENT
10^{-20}
10^{-31}

Once anything is inside this horizon there is no way it can get out. And if quarks have an event horizon around them we would never be able to detect them.

Well, so much for speculation. Getting back now to the events of the Hadron Era we find the universe continuing to expand rapidly. But it is still a small universe, perhaps about the size of our planet Earth. The temperature is dropping quickly, and finally the second of our four basic forces, the weak nuclear force, breaks away. A little later it is followed by the electromagnetic and the strong nuclear force. By the end of the Hadron Era, all forces have separated out and have changed significantly in strength.

There are some, however, who do not believe the separation occurred this early. Victor Elias and Jogesh Pati of the University of Maryland and Abdus Salam of the International Center for Theoretical Physics in Trieste have suggested that the unification lasted much longer than this. In fact, they believe that we might still be able to find evidence of the unification in cosmic rays, or perhaps when accelerators are built slightly larger.

One ten thousandth of a second after time zero, the Hadron Era was over and the temperature was down to 10^{12} K — a mere trillion degrees (assuming the elementary particle model, of course). The universe then entered the *Lepton Era*. This was primarily a time of decomposition and annihilation of particles. First the neutrinos decoupled (that is, the universe became for the first time "transparent" to them) and began a free expansion. Then the electrons and positrons began annihilating one another, creating photons which would also soon decouple (at a temperature of about 3000 K) and spread into the universe giving rise to what we now call the "fireball radiation."

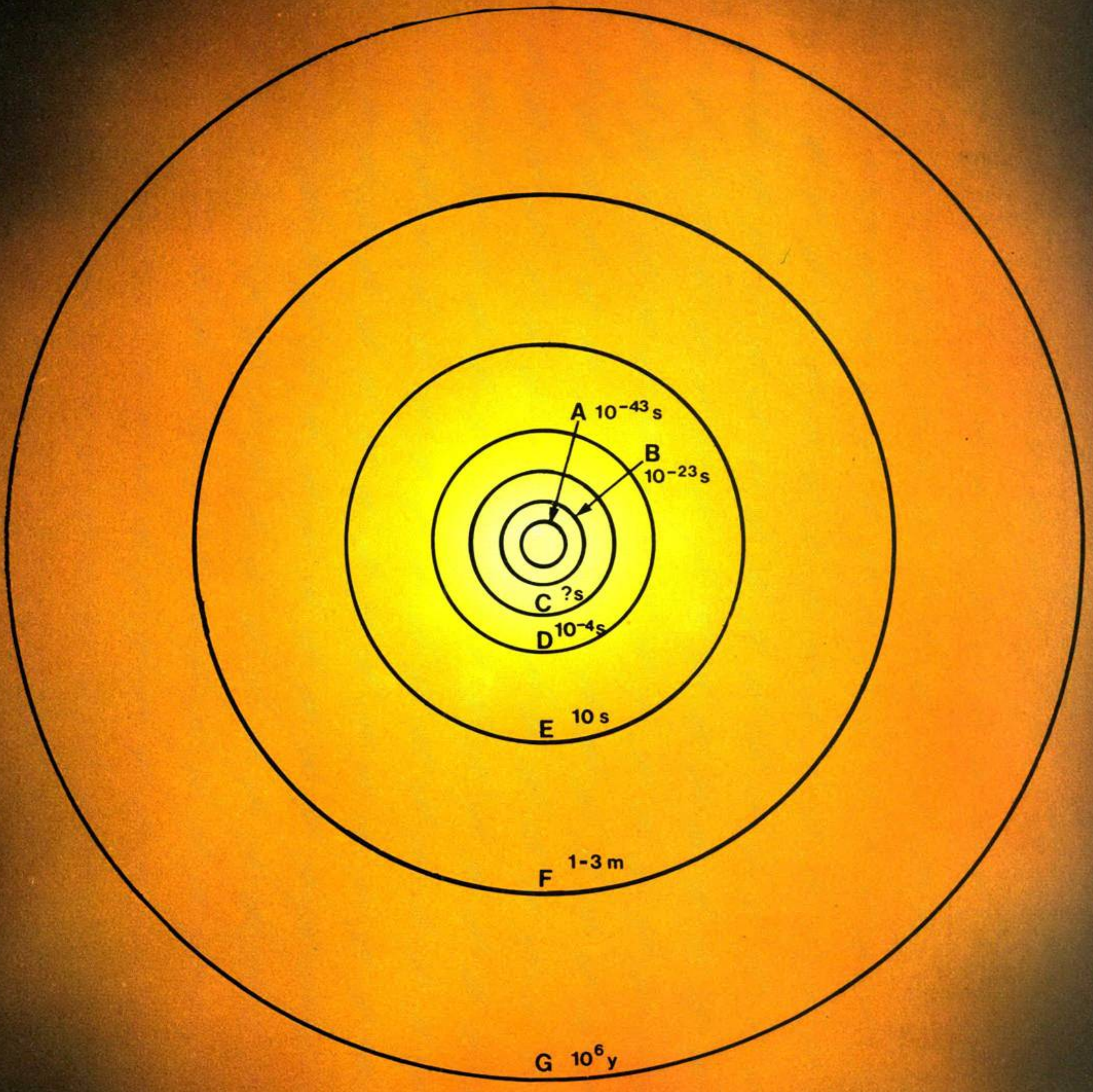
The detection of this cosmic background radiation, now cooled down to 2.7 K, was one of the best confirmations we have had of the Big Bang theory. It is interesting that although this radiation has been detected, scientists have not yet detected the remnant neutrinos. Their temperature should now be about 2 K. If this neutrino remnant could be found, it would strongly reinforce our present model of the Big Bang.

Continuing our look at the Lepton Era, we find a rapid transformation of matter into energy by the process of matter-antimatter annihilation. The resulting radiation spread out into the universe and within ten seconds the universe was "radiation dominated." Most of the electrons and positrons had disappeared and few other particles were left. Thus, the universe is said to have entered the *Radiation Era*.

An important event in the history of the universe was still to take place. So far the universe had consisted only of elementary particles (and perhaps black holes), but it was now cool enough for the first atomic nuclei to form.

A theory describing how these nuclei arose was formulated by George Gamow and Ralph Alpher in 1948. As they were getting ready to publish, the irrepressible punster Gamow had a clever idea. He noticed that his and Alpher's names sounded like the Greek letters gamma (γ) and alpha (α). But he needed a beta (β) to complete the α-β-γ sequence (the first three letters of the Greek alphabet). So when he and Alpher published the paper, he added the name of Hans Bethe of Cornell University. Bethe was no doubt surprised to find his name on a paper he had nothing to do with! Anyway, the theory eventually became known as the Alpher-Bethe-Gamow, or α-β-γ theory.

According to this theory, when the primordial nucleus exploded, it broke down into neutrons which in turn rapidly decayed to protons and electrons. The free protons were struck with great force by the remaining neutrons and gradually built up stable nuclei of increasing complexity. The chain presumably started with an H^1 nucleus (a proton). The addition of a neutron to this proton


A 10^{-43} s
B 10^{-23} s
C ?s
D 10^{-4} s
E 10 s
F 1-3 m
G 10^{6} y

produced an H^2 nucleus, and so on all the way up through the heavy nuclei. Unfortunately there was a flaw in the idea. There was a gap after He^4 (helium) that could not be overcome. Even if the He^4 nucleus is struck with great force by a neutron, it will not bind that neutron to itself. A nucleus with five particles in it is just too unstable. A similar problem arises for a nucleus with nine particles. It is possible, of course, that two neutrons might hit the helium nucleus simultaneously. In this case lithium (Li^6) would be formed — but the probability that this would actually happen is small. Thus, the α-β-γ theory could account for H^2, H^3, He^4 and possibly a little Li^6, but nothing more.

However, the theory was far from being a complete failure by any standard. An important consequence of it was the prediction of fireball radiation. Gamow originally estimated that it should have a temperature of about 25 K, but R. Herman and Alpher later corrected a number of arithmetic errors he had made (Gamow was notorious for this) and reduced it to about 5 K. The theory also successfully predicted the relative abundance of hydrogen and helium observed in the universe (about 3 to 1).

There is still a problem, though. If nuclei were not produced in the Big Bang, where *did* they come from? We have since learned they were generated in the cores of stars. When these stars exploded, they spilled their nuclei out into the universe. These nuclei eventually went into new stars, and some of these second-generation stars (our own Sun, for example) developed planets. It's hard to believe that the atoms (with the exception of hydrogen and some helium) here on Earth — even those of your body — were once generated deep inside stars. But it's true.

Few significant changes were now taking place in the universe. The Radiation Era continued for about a million years. The density decreased considerably during this time and by the end of the Radiation Era, it was down to about 10^{-20} gms/cm. The temperature also continued to fall to about 3000 K. At this temperature the universe was finally cool enough for nuclei to begin accumulating electrons, which means stable atoms could form. This event brings us to the era we still live in: the *Matter Era*.

Understanding the formation of the galaxies is the main concern of this era. The first serious theory of galactic formation was proposed decades ago by Sir James Jeans. He assumed the universe was uniformly filled with a gaseous fluid, and examined the clumping that would result from the action of gravity. His theory soon ran into serious problems, however — the largest mass accumulations possible were only the size of globular clusters.

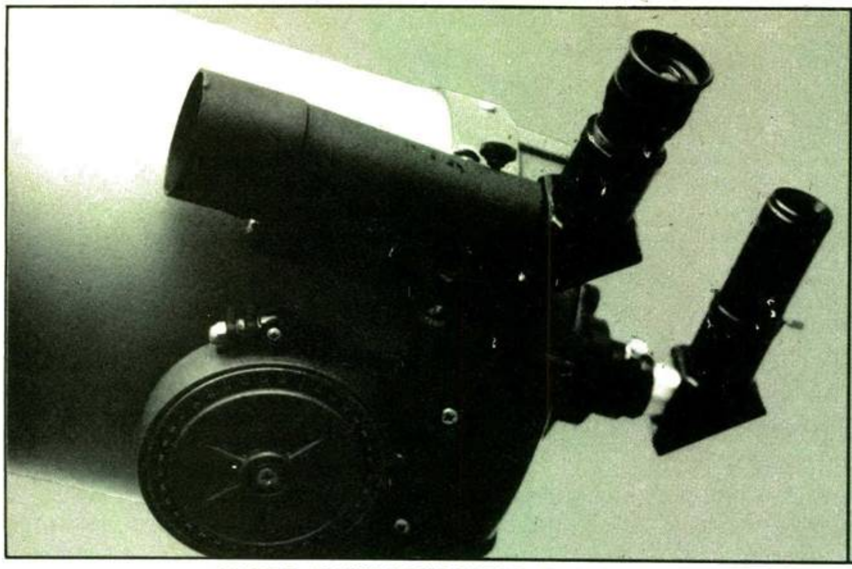
E.M. Lifshitz of the U.S.S.R. Academy of Sciences modified the theory in 1946 to allow for the expansion of the universe. The results were better but still not entirely satisfactory. Indeed, it now seems that a thorough understanding of the initial fluctuations will be needed before a completely satisfactory theory can be formulated.

An alternative approach to the problem of galaxy formation centers around black holes. Several authors have suggested that black holes may have been the "seeds" around which galaxies grew. There are, unfortunately, problems with this idea. How, for example, do we account for the evolution of galaxies in terms of this seeding? In other words, once the galaxy forms around the black hole, how does it change as it ages — and why? Obviously, the black hole at the core would affect its evolution. But so far no one has given a satisfactory account of just what would happen.

Another idea is that galaxies form around white holes. Indeed, there even seems to be some evidence for this point of view. White holes have matter pouring out of them, rather than pouring into them (as in black holes). This means, in effect, that they would appear to be sources rather than sinks. And it is well known that both Seyfert galaxies and quasars appear to have some sort of "source" at their cores. But again there are problems. Douglas Eardley of Yale University has shown that even if white holes had been formed in the Big Bang they would soon have changed into black holes.

And so it goes. Sometimes it seems that for each step forward we make two backwards. But somehow in the end, progress is made. Much has been learned about the early universe in the last few years. Astronomers can now piece together a reasonable picture of what happened, but many questions remain. Why haven't we detected the remnant neutrinos? And what about the quarks — the elementary particle theory depends on their existence. And finally, we still don't know exactly how the galaxies were formed. For all we have learned, a great many fascinating questions still remain to be answered.

As the universe expanded, both its temperature and density quickly dropped. This "thinning out" and "freezing" led to a series of practically instantaneous events highly significant for the present universe. Some of these were: A Gravity breaks away from the unitary primeval force as a separate entity. B Primordial black holes are generated by extreme pressures. Free quarks may also have been produced at this stage, and some may still be present in the universe. C Next, the second of the four forces, the weak force, breaks away and establishes its own identity. D Neutrinos "decouple" and begin to expand freely rather than being maintained in a thermal equilibrium with the other constituents of the universe. There should be a cosmic "neutrino background" as a result of this event. E The decoupling of matter and radiation makes the universe transparent to electromagnetic radiation, detectable today as the cosmic microwave background. The universe has become radiation dominated. F The first atomic nuclei begin to form with the generation of helium in a ratio of about one helium nucleus to three hydrogen nuclei (protons). This is about the relative cosmic abundances of these two elements observed today. G With the energy density of the universe now low enough, electrons begin combining with nuclei to form stable atoms for the first time. The essential constituents of the universe have now all been established, and it only remains for the matter to organize itself into the stars, galaxies, and clusters of galaxies we see today. Painting by Mark Paternostro.



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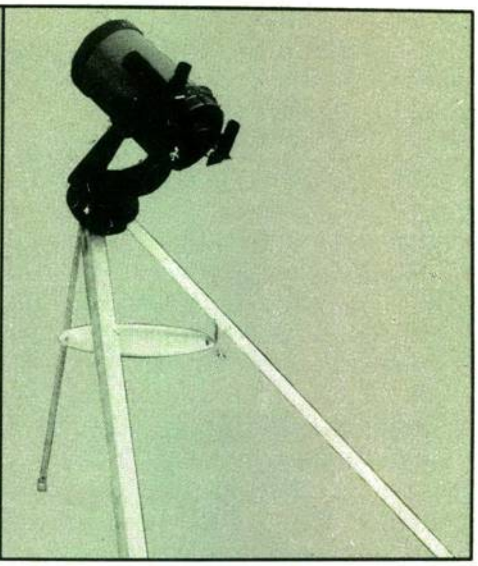

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The Sun-grazers

by
Joel Davis

From a place so distant that the Sun's light takes over a year to reach it, they come. The trip takes uncounted thousands of years, and for most of it, they are unnoticed by the sky watchers of the third planet.

But during the last months of their journey, they are indeed noticed. The show they put on is spectacular.

They are called sun-grazers. They are comets. And they are the most awesome of those heavenly objects that have terrified, inspired, and baffled humans for all of history.

Though most people think of comets as huge objects with tails millions of miles long, they're actually about as close to nothing as something can get. The *nucleus* of a comet is a chunk of rock, dust, and ices no more than 50 miles in diameter. As this "dirty iceberg" — so called by astronomer Fred Whipple — gets closer to the Sun, it develops a *coma*: a spherical cloud of dust and gas that can extend a hundred thousand miles out from the nucleus. The coma forms as material is blown off the nucleus' surface by the Sun's heat and the solar wind.

Only if the comet crosses the orbit of Mars will a tail begin to develop. As the Sun's heat and the solar wind become stronger, material from the coma begins to stream away from the Sun. Sometimes two tails develop — one of dust and one of ionized gases — but stars shine clearly through both.

Left: The inner tail and coma of comet West have dimensions thousands of times greater than the tiny "frozen iceberg" that produced the comet. Photograph by William Hughes. Right: Comet Ikeya-Seki, a sun-grazer, was a spectacular sight in 1965's pre-dawn skies after its hair-raising passage past the Sun at a distance of only one-third of a million miles. Kitt Peak National Observatory photograph © 1979 AURA, Inc.

As the comet swings around the Sun at its closest approach (perihelion), the tail swings with it. And as the visitor from afar heads back into the depths of space, its tail precedes it, still being blown away from the Sun by the force of the solar wind.

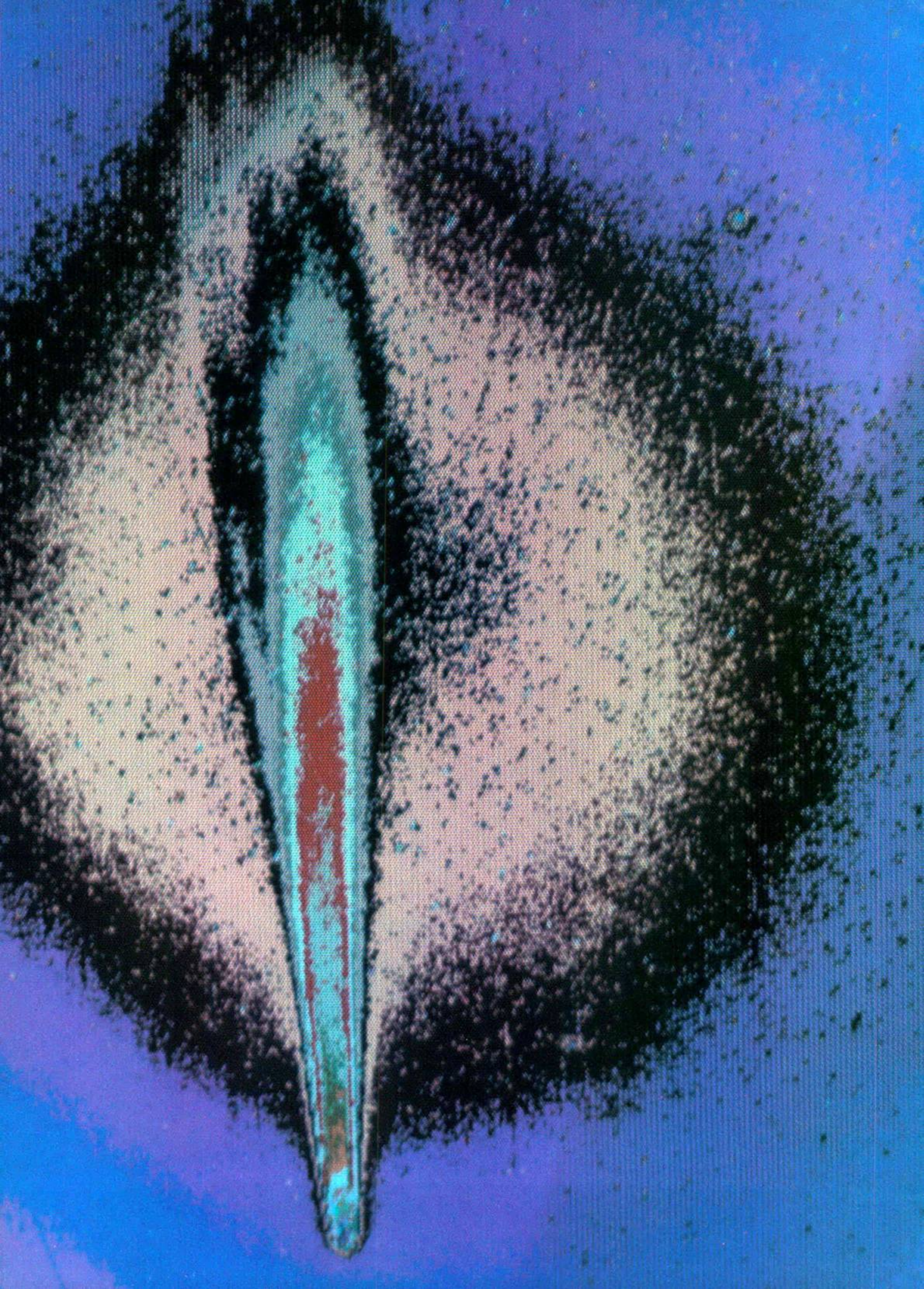
Do comets come from interstellar space? Are they cosmic "strangers in the night" that are captured by the Sun's gravity only to escape back to the void between suns? Apparently not. If they were, a sizable number of them would travel in hyperbolic orbits resembling a hairpin bent wide apart. Such an orbit is open, and the comets would never return. But no comet has ever been observed that had an original orbit proven to be open.

Instead, comets probably originate in the *Oort cloud*, a vast halo of material weakly bound to the Sun by gravity. Named after astronomer Jan Oort who originally proposed the idea, the Oort cloud extends from three to ten trillion miles from the Sun. That is nearly half the distance to the nearest star, and so the solar system assumes an almost mind-boggling size.

The Oort cloud itself, and the comets that compose it, may have been formed by the Sun capturing matter from between the stars. Or the cloud may have been formed along with the rest of the solar system, some five billion years ago. Icy and rocky material from the region of Uranus and Neptune could have been hurled out by the gravitational forces of those two planets to form the cloud. Still another theory proposes that the Oort cloud formed just where it is and that the comets are the frozen leftovers of the solar system's creation.

But the theory that comets come from the Oort cloud isn't in dispute. Most likely the dirty icebergs are wobbled out of their creeping orbits by the gravitational actions of passing stars. Slowly, the fragile conglomerates of dust and ice deviate from their age-old paths. Some head out and are lost forever; some head in.

Most comets visible to the naked eye travel in



extremely stretched-out orbits that look like elongated cigars. The outer end of the orbit lies in the Oort cloud. The *long-period comets* take several thousand to several million years to complete one turnaround on their highly elliptical paths. *Short-period comets*, with orbital periods similar to those of the planets, are simply long-period comets that have been "captured" by a giant planet such as Jupiter or Saturn. Halley's Comet, with a period of 76 years, is one such short-period comet. That great disappointment of 1974, comet Kohoutek, was a long-period comet. It will be millions of years before Kohoutek again approaches the Sun. Perhaps our distant descendants will have a better show than we did.

And where do the sun-grazers fit into the scheme of things?

Sun-grazers are comets that come within a Sun's diameter of the solar surface at their closest approach. There are at least a dozen comets that would fit this category, but the ones usually referred to as the sun-grazers belong to a curious entity called a comet group.

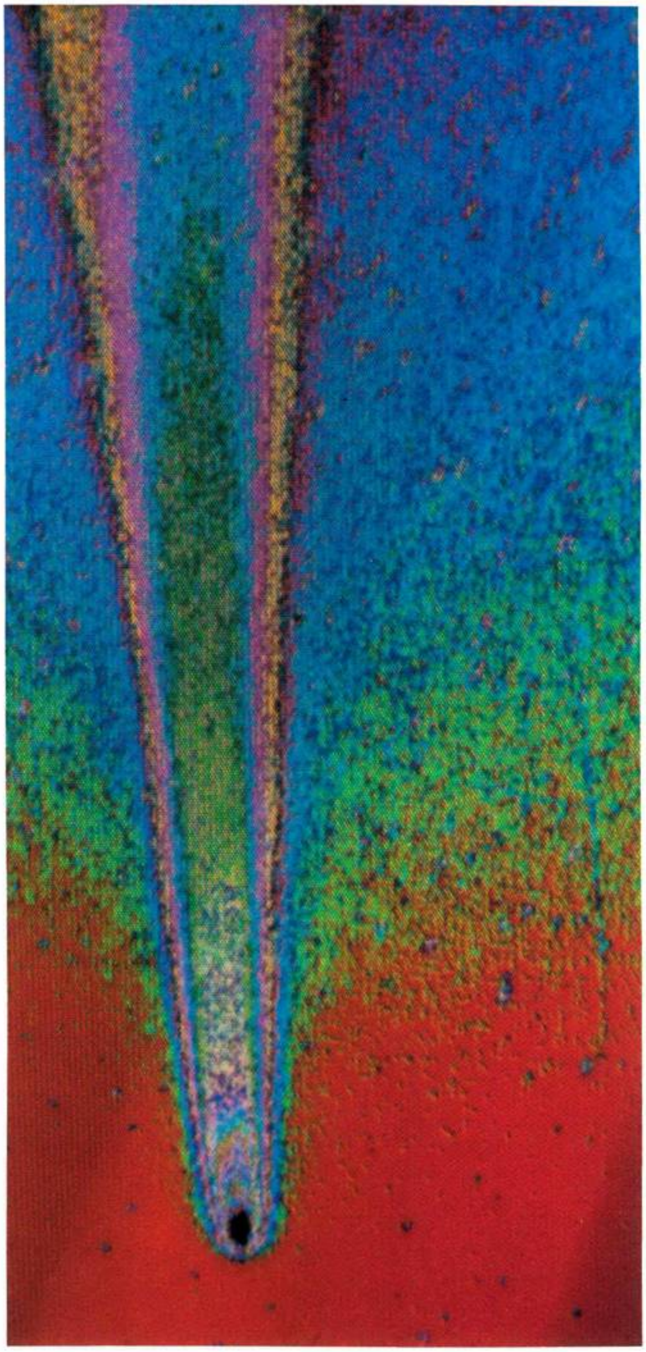
Comet groups shouldn't be confused with comet families. A comet family is a collection of comets whose aphelia, or furthest distance from the Sun, center on the orbit of a particular planet. They have, in effect, been captured by the gravitational influence of Jupiter, Saturn, Uranus, or Neptune. Jupiter has the largest comet family, of course, and the others each have their own retinue, also.

But a comet group is different. It is a collection of comets that all travel in the same orbit. As an imaginary comparison, one might speak of a "planet group" as two or more planets that occupy the same orbit. If more than one planet traveled in Earth's orbit, we could speak of an "Earth group" of planets.

Planet groups don't exist. The five-plus billion years of the solar system's existence has been plenty of time for the planets to sweep their orbits clean of any potential rivals. Not so for comets. New ones constantly plunge in from the Oort cloud. And while each one has its own orbit, sometimes a catastrophe happens. It could be a collision with some piece of matter; or during its approach to the Sun, the nucleus may heat up unevenly; or while it's spitting out dust and gas under the influence of the Sun's wind, one jet of matter may become unusually strong. The nucleus splits into several different pieces. Because each piece follows almost the same path in the future, each arrives back at the Sun at a slightly different time. The result: a comet group.

Fifteen comet groups are well-known, and are named A through Q. The sun-grazers are group M.

The eight known members of group M deserve the name sun-grazers. With one exception, they have all had approaches to the Sun of less than 500,000 miles. They dive in closer to Sol than any other object in the solar system. Comet 1843 I and comet 1880 I came within 79,000 miles of the Sun's surface. Comet 1882 II (the "Great Comet of 1882") approached to 283,000 miles, while 1887 I and 1945 VII reached close-in distances of 469,000 miles and 153,000 miles respectively. Comet Ikeya-Seki (1965 VIII) came within 307,000 miles. But the record holder is comet Pereyra (1963 V): it came within 60,000 miles of the solar surface at its closest approach.



Kitt Peak researchers made these isodensity images of comet Halley's spectacular flyby to see what kind of information they could extract from the original Lowell Observatory plates. The original plate for the overall view (left) and close-up (above) was taken May 10, 1910, and shows the comet at its maximum size. Halley's is a short period comet, probably captured from a much larger orbit by one of the giant planets. Photographs © 1978 AURA, Inc. and Lowell Observatory.

Only the comet of 1668 at its closest approach to

the Sun was more than half a million miles away from the Sun's visible surface. Its perihelion distance was about 6 million miles — still well within the orbit of Mercury, the closest planet to the Sun. But the others all came so close that they streaked through the corona during their closest passage.

Not only did the sun-grazers all come perilously close to the Sun, but they all followed almost exactly the same orbit in their journeys. Comet 1668, along with comet 1843 I and comet 1880 I, had an orbit inclined at about 144° from the plane of the Earth's orbit around the Sun. The others all have orbits with practically the same inclination. All eight sun-grazers approach the Sun from *below* Earth's orbital plane, and they all follow a *clockwise* direction as they come around and fly away.

If we were to sit in a space vehicle high above the Sun's north pole and somehow speed time up while looking down on the solar system, the planets would appear to speed around the Sun in a counterclockwise direction. Every planet but Pluto would lie very close to an imaginary plane passing through Earth's orbit. But the sun-grazers would appear to come from a point below the plane, climbing up toward the Sun. Their approach is very direct; they are seemingly aimed right at the heart of the Sun! But in the last instant they flash through the corona and whip around the Sun at a blurring speed. Then the tail becomes spectacular as the sun-grazer heads back out toward trans-plutonian space. Its orbit will take it so far out from the Sun that it will be at least a thousand years before it returns.

Left: As the nucleus of comet Bennet 1970 was heated by sunlight, fountains of gas poured from its surface. Still spinning from the rotation of the nucleus, and pushed away from the sun by pressure from the solar wind, the streams of gas look like a giant pinwheel in this high resolution close-up. Photograph © 1970 Lunar and Planetary Laboratory. Above: Comet West 1975 sprays two tails away from the Sun in this predawn photograph by Marvin Mayo. Nearly perpendicular to the horizon is a tail of gases; tending toward the left, and banded, is a tail of fine dust particles.

It's not too difficult to guess how the sun-grazer group, group M, was formed. At some time in the past a single large comet came perilously close to the Sun. Whether this was its first close brush with Sol, or whether it had survived several previous encounters is not important: this time it didn't make it.

The gravitational stresses were too much: the nucleus was heating up unevenly and huge fissures developed in the conglomerate of ices and rock. Fountains of gases erupted, and acting like rocket exhausts, set the nucleus spinning — setting up still more stresses in the dirty iceberg. At some point, it broke apart. The pieces drifted away from each other, but not too quickly — perhaps at no more than a few miles per second.

Eight have appeared in the last 300 years. One appeared in 1668, then a cluster of four between 1843 and 1887, and three more in this century.

The most recent sun-grazer to blaze across our skies was Ikeya-Seki (1965 VIII). A classic example of a sun-grazer, Ikeya-Seki could well have been called "The Great Comet of 1965" if such nomenclature were still in use. Like the Great Comet of 1882, lucky observers had a chance to see it in broad daylight. It shone brighter than the full moon. People in the southwestern United States were the lucky ones. Observers in the rest of the U.S. were less lucky — cloudy skies blocked the view.

But the daylight view was just the beginning. Its surface boiling from the close brush with the sun — Ikeya-Seki swept down to 307,000 miles above the solar surface and whipped around the Sun in just six hours — the comet began to develop a spectacular tail as it headed back out. It twisted and turned like a lace curtain in the solar wind. In the morning sky, the tail stretched up like a searchlight, covering a full 25° of arc. Its 75 million mile length was almost as great as the distance from the Sun to Earth. Only three other comets have had longer tails. (The all-time record for tail length, 200 million miles, is held by comet 1843 I — another sun-grazer.)

Ikeya-Seki was a gold mine for astronomers. For the first time, a comet's temperature was taken. From a temperature of 700° Fahrenheit, when it was 45 million miles from the Sun, it heated up to 1200° when it was only 20 million miles away.

Some surprising things were learned about the composition of Ikeya-Seki, too. Shortly after the comet's closest approach to the Sun, the Lick Observatory's 120-inch telescope was used to take emission spectra of a region several thousand miles in diameter within the comet's head. The ultraviolet spectrum clearly showed the presence of iron, nickel, chromium, and calcium. The visible spectrum strongly showed the presence of sodium, and the UV spectra indicated the possible presence of copper, potassium, and a cyanogen compound.

But perhaps the most interesting development was also the least surprising — after all, Ikeya-Seki was obviously a near twin of 1882 II. Fifteen days after its closest approach to the Sun, the nucleus of Ikeya-Seki broke apart. A second distinct nucleus appeared in photos taken at the U.S. Geological Survey's station in Flagstaff, Arizona. And as the distance between the two increased, the brightness of that second nucleus faded. By working backward in time, astronomers estimated that the comet's nucleus probably began to split only three days after its swift passage above the solar surface. The Great Comet of 1882 had done exactly the same thing.

What does the future hold for the sun-grazers, and those who watch them? Ikeya-Seki, or its two fragments, will not return for at least another thousand years. But will we have to wait that long for another sun-gazer to light up the skies?

It's hard to say. The proto-sun-grazer may have broken into only eight pieces; or perhaps there have been 10 so far — the number of observed sun-grazers is in dispute. But perhaps there were more fragments — 12 or 15 or more. No one knows. And no one will know until the next sun-grazer bears down in a near bull's eye on the Sun.

Joel Davis is a science writer living in Spokane, Washington. He recently contributed "Is There a 'New' Lunar Crater?" to ASTRONOMY and has also appeared in **Future** *and* **Omni**.

ASTRONOMY forum

On Building Telescopes

Memorial Day weekend found your Editor 7300 feet high in the San Bernardino Mountains of southern California attending an extraordinary gathering of amateur astronomers. Called the Riverside Telescope Makers Conference, the annual event drew a record crowd of 700, plus about 200 telescopes, despite some fears that gasoline shortages would keep many people away. These mountains are very beautiful, exotic to an easterner (as I am), extravagantly proportioned, and steep; their proximity, majesty, and clean air are no doubt instrumental in spurring a vivid environmental awareness in Californians. In these mountains, under clear skies, I spent three nights and four days in the company of people sharing a common love of the stars.

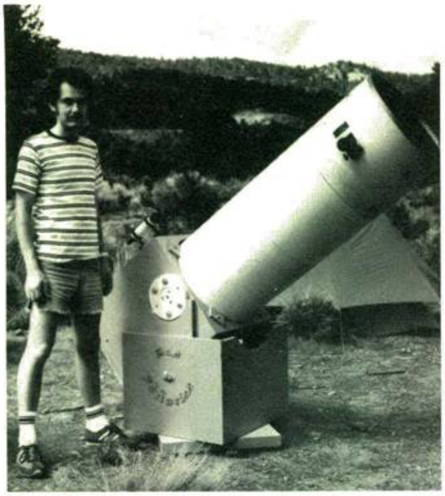
During the day I strolled around the campsite where the meeting is held (Camp Oakes, near Big Bear), looking at telescopes, talking to their owners, taking hundreds of photographs, joining in dozens of friendly informal groups. Each night after dark the Conference became what must be the biggest annual star party held anywhere in the world.

Jeff Schroeder's 11" Refractor

The setting, under a profoundly dark sky, ringed by mountains, was magnificent; standing in the middle of the main field I could hear the pleasant sounds of people observing, Messier numbers, eyepiece focal lengths, and exclamations drifting on the wind. The biggest telescope, and one of the first there Friday afternoon, was Mike Hatcher's 22-inch Newtonian reflector, mounted in a simple alt-azimuth fashion. Aiming involved giving it a good solid push over to the part of the sky I wanted to look at, a few thumps on the tube to center the object in the target field, then setting the ladder in place and climbing up to the eyepiece. I can only hint at the thrill of seeing knots and dark lanes in M-51's spiral arms with it, or the central star in the Ring Nebula, the intricate laciness of the Veil Nebula, thousands of stars in a globular, or the Andromeda Galaxy filling the field.

The number of telescopes was incredible. The official registration sheets showed 200 telescopes, but of course people didn't bother to register their little ones, such as 6-inchers; they just signed in the big ones. I didn't count 16-inch telescopes, but there were easily a dozen; there was an 18-incher, a smattering of 14's, and quite literally many dozens of 12's. The most common size may have been 10-inchers; I'd estimate there were 100 of them there. Most were Newtonian reflectors, some of them outstanding examples of craftsmanship. Nor was there any shortage of smaller instruments: each large instrument seemed surrounded by a retinue of smaller ones.

Most of the telescopes were homemade; it was, after all, a telescope maker's meeting. Many participants spent all of one or more days wandering from telescope to telescope, talking to the owners, picking up new ideas, construction hints, or giving


Doug Berger's 16" Newtonian

Arnold Schwartz' 8" Newtonian

Mike Hatcher's 22" Newtonian

advice gleaned from building their own.

Particularly outstanding was Jeff Schroeder's 11-inch refractor, towering 20-some feet high — a fine instrument, all homemade including the objective lens. I regret that I didn't get around to seeing Saturn with it, but it was superb on M-13. Mack Wagner's 10" horizontal solar telescope, using a flat mirror to direct sunlight into a stationary refractor, gave fine views of the Sun in H-alpha. Doug Berger (co-discoverer of comet Kobayashi-Berger-Milon) and Earl Watts brought their alt-azimuth 16-inchers; Arnold Schwartz had a tidy 8" f/6 Newtonian on an all-wooden mounting; and Duane Niehaus had a rock–steady pier for his 5" RFT reflector.

An illuminated table and chart filing system for transparent charts, built by Blayne Lequex, won a Merit Award as the "Best Observing Accessory." And Pierre Schwaar won a citation for "Most Daring Mechanical Engineering" with his 16" telescope that maintained the observer, riding in a chair, within comfortable reach of the eyepiece. He uses the instrument to popularize astronomy by giving "Tours of the Universe" with it; the "tourist" rides at the eyepiece while Pierre swings the telescope around the sky locating object after object with the 6" finder telescope on the side.

One evening, at the eyepiece of a 16" telescope, I explored the stretch of Milky Way between M-6 and M-7 and the Scutum Starcloud, poking along from object to object — the rich starry areas of the Sagittarius Starcloud, M-8, M-20, the globular M-22, north to M-

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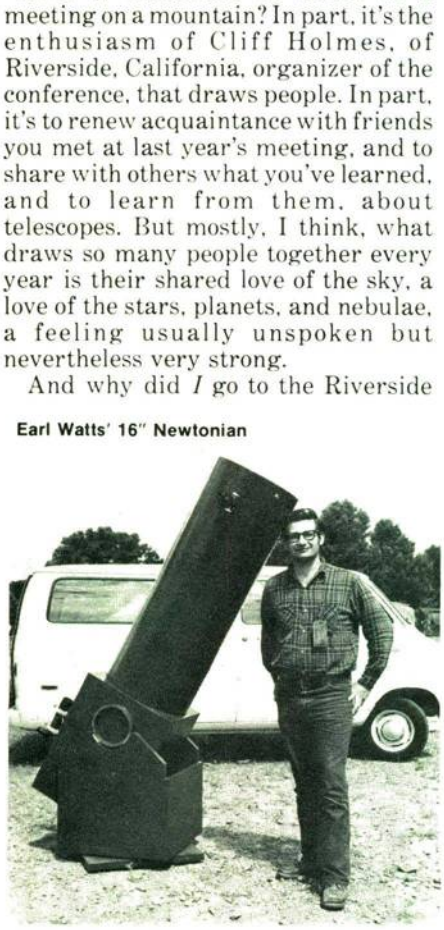
Stephan's Quintet - 200" Hale photo

16 and M-17 — making a careful inspection of the seemingly endless numbers of clusters that lie in that stretch of sky. Drifting over to other telescopes, I was treated to more delights: the edge-on spiral NGC-4565, its dust lane easily seen, the Sombrero Galaxy, Saturn in Arthur Leonard's 6-inch "Yolo" tilted-component telescope, and on the last evening I saw Stephan's Quintet, a distant group of galaxies that I've always thought of as a "200-inch object." It's not; in Earl Watts' 16-inch under good skies, it's about as easy as the Virgo cluster galaxies are with a 4-inch telescope.

What draws these lovers of the sky, these *amateur* astronomers ("amateur" from the Latin *amator*, meaning "lover"), hundreds of miles to a meeting on a mountain? In part, it's the enthusiasm of Cliff Holmes, of Riverside, California, organizer of the conference, that draws people. In part, it's to renew acquaintance with friends you met at last year's meeting, and to share with others what you've learned, and to learn from them, about telescopes. But mostly, I think, what draws so many people together every year is their shared love of the sky, a love of the stars, planets, and nebulae, a feeling usually unspoken but nevertheless very strong.

And why did *I* go to the Riverside Telescope Makers Conference? In part, I went as the Editor of ASTRONOMY, now the largest English-language astronomical magazine (there's a bigger Japanese magazine). But mainly I went as the Editor of **Telescope Making**, our new publication for people interested in telescopes, and because I too am one of those "star lovers."

Earl Watts' 16" Newtonian



I also went because I wanted to see what was happening at the Riverside Telescope Makers Convention; I went because Ben Mayer and Dennis DiCicco said that good things were happening there. I went because I wanted **Telescope Making** magazine to be there.

Some time ago, about 18 months in fact, I faced up to the fact that we simply couldn't fit any real amount of information about telescope making into this magazine. I also realized that although some of our readers wanted that telescope making information, most didn't. As a telescope maker myself, I felt frustrated. So, after mulling it over for a while, we created another magazine, **Telescope Making**, that comes out quarterly. Because the Riverside meeting is such a major event, and because it'll be covered in **Telescope Making*4**, I'd like to offer the telescope makers reading this a free sample copy. If you send me an 8½" x 11" or 9" x 12" self-addressed clasp envelope with 67 cents postage on it, I'll send you a copy of **TM*4**. (You can fold the big envelope and stuff it into a standard business envelope.) Of course I hope you'll subscribe to **Telescope Making** after seeing a copy!

Richard Berry

Moons That Weren't

The search for new objects in the solar system has been a major enterprise of observational astronomers since the first use of the telescope. Three planets, at least 31 satellites, thousands of asteroids, and numerous comets are among the fruits of these efforts, and there is every indication that more objects in at least the latter three categories are yet to be revealed as the methods for searching improve, pushing the limits down to smaller and smaller bodies at the outer reaches of the planetary system.

But as in any process of search and discovery there are false starts and erroneous identifications — such is the progress of science. The history of the study of the planets and their satellites reveals a number of fascinating cases of incorrect or unconfirmed identification of satellites. Let's take a look at a couple of these cases, ranging in time from the earliest telescopic observations of the planets through modern times.

Venus

Patrick Moore, in **The Planet Venus**, tells the story of what was perhaps the earliest example of an erroneous satellite observation, the phantom moon of Venus. The first reported sighting was made by J.D. Cassini observing from Paris in 1686, although it appears that some object was seen earlier but not reported by the Neapolitan amateur observer Francesco Fontanna in 1645, and by Cassini himself in 1672.

Cassini wrote: "1686 August 18th, at 4:15 in the morning. Looking at Venus with a telescope of 34 feet focal length, I saw at a distance of 3/5 her diameter, eastward, a luminous appearance, of a shape not well-defined, that seemed to have the same phase with Venus, which was then gibbous on the western side. The diameter was nearly one quarter that of Venus." Cassini went on: "I had seen a like phenomenon, which resembled the phase of Venus on 1672, Jan. 25...Venus was then horned, and this object, which was of diameter almost one quarter that of Venus, was of the same shape." Both of Cassini's observations were made in the early morning, prior to dawn.

The venusian moon remained in limbo for over half a century. Then on November 3, 1740, James Short, a mathematician and instrument maker, saw the phantom moon again under favorable seeing conditions with a 16½-inch reflector. Short reported that the nearby object's diameter was about one-third that of Venus, and although not brilliant, was quite sharp, well-defined, and showed the same phase as the planet. He viewed the object for an hour using three eyepieces and even a different telescope as a precaution against visual illusion. This was Short's first and last sighting; he never managed to find it again.

In 1761, Montaigne, observing from Limoges in France, appears to have confirmed the satellite's existence with not one, but a series of four sightings. On May 3, 4, 7 and 11 in 1761 (the intervening nights were cloudy), Montaigne saw a crescent one-fourth the size of Venus with the same phase and at a distance of 22 minutes of arc. It occupied a different position each night, appearing to revolve in orbit about its primary. The moon appeared much as Cassini had described it. Though he had previously felt dubious about its existence, Montaigne was now convinced. He had taken every precaution against optical illusion, including observing the satellite when Venus itself was outside the field of view.

Additional reports of the satellite came during the next few years (notably during the 1761 transit of Venus), but the last report of the phantom moon appears to have been made in 1764. Thereafter, the great observers J. Schröter, William Herschel, and later E.E. Barnard, with their superior telescopes, could never detect any anomalous objects near Venus. Gradually the nonexistence of the venusian satellite was accepted inspite of the earlier observational evidence. (But strange disappearance notwithstanding, there were still supporters of the venusian moon in the 19th century.)

In 1887 Paul Stroobant of Brussels collected 33 recorded observations by 15 observers and subjected them to a critical analysis in an attempt to clear up the mystery. He found that some observations could be dismissed entirely, such as those during the 1761 transit, since many astronomers with better telescopes observed simultaneously without detecting any shadow following Venus. Others could be put off as observations of stars. Stroobant's conclusion (which still stands) was that the observations of a crescent satellite by Cassini and the rest were due to optical illusions or ghost images in the telescope.

Mars

In contrast to Venus, Mars *does* have moons: Phobos and Deimos. The two martian satellites were discovered in 1877 by Asaph Hall, but their existence had been predicted much earlier. The "inventor" of the martian moons was Johannes Kepler, a contemporary of Galileo. Kepler was a first class mathematician, but he was also the product of a more mystical intellectual climate than the present. Kepler had an innate faith in the symmetry of nature, and constantly sought numerological relations in the celestial realm. Thus when he heard of Galileo's discovery of four jovian moons, he immediately postulated the existence of two martian satellites. To understand how this occurred to Kepler, look at the known number of solar system members in the early 17th century:

Planet	Moons
Mercury	0
Venus	0
Earth	1
Mars	?
Jupiter	4
Saturn	0

Kepler reasoned that since the distance from Mars to the Sun was intermediate between those of Earth and Jupiter, Mars must also have an intermediate number of satellites. Kepler could have deduced two or three moons for Mars, but his predilection for geometrical progressions led him to predict two.

Kepler's prestige was immense, particularly after his three laws of planetary motion were published, and so faith in the existence of two martian satellites persisted. At the beginning of the eighteenth century, this idea seemed even more plausible, for by this time astronomers had detected five satellites of Saturn and were aware of the large gap in distance between the orbits of Mars and Jupiter. An as-yet-undetected planet was proposed to be orbiting in this gap. The solar system as known then was:

Planet	Moons
Mercury	0
Venus	0
Earth	1
Mars	?
Undetected planet	?
Jupiter	4
Saturn	5

The general consensus seems to have been that Mars must have two satellites, as Kepler had deduced, and the undetected planet three.

A much more unusual reference to the martian moons was made by

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Jonathan Swift in his 1726 political satire, **Gulliver's Travels**. At one point in the book, Gulliver visits the flying island of Laputa. Gulliver recounts the discovery of the two satellites as told to him by the astronomers of Laputa:

> *"They have likewise discovered two lesser stars, or satellites which revolve about Mars; whereof the innermost is distant from the Center of the primary Planet exactly three of his Diameters, and the outermost five; the former revolves in the Space of ten Hours, and the latter in Twenty-one and an Half; so that the squares of their periodical Times, are very near in the same Proportion with the Cubes of their Distance from the Center of Mars; which evidently shows them to be governed by the same Law of Gravitation that influences the other heavenly Bodies."*

Note that Swift knew Kepler's third law of planetary motion! In terms of the diameter of Mars, the real orbital distances for Phobos and Deimos are 1.4 and 3.5 respectively, and their actual periods of revolution are 7 hours 39 minutes for Phobos and 30 hours 18 minutes for Deimos.

The most plausible explanation for Swift's prediction was suggested by K. Ludendorff. Suppose that after accepting Kepler's hypothetical martian moons, Swift considered possible orbits for these two satellites. He may have deduced that the moons must be close to Mars, which would explain the difficulty in observing them. He could then look to Jupiter for an example. The two closest jovian satellites known at that time were Io (J1) and Europa (J2), which are about 3 and 5 jovian diameters distant from Jupiter's center. Assuming a similar configuration for the martian system, it would be easy to use Newton's gravitational theory and Kepler's laws, which he obviously knew, to determine the orbital periods.

Saturn

By the end of the 19th century, Saturn was known to have 9 moons, the last discovered being Phoebe, which was found by William H. Pickering in 1898. In 1905 Pickering announced the discovery of a tenth satellite. Themis, as he called it, had been recorded on several different photographic plates during the course of his study of S9 (Phoebe). He then worked out an orbit which placed Themis at a distance from Saturn of 1,462,000 kilometers, or 5 ring-diameters.

But Themis was never seen again. Detailed comparison with deep photographs of the background star fields shows that where Pickering thought a satellite was seen, nothing more than faint stars exists, though the orbit where Themis was placed is likely to contain a satellite (on dynamical grounds) because of a gravitational resonance with Titan.

Recent books about Saturn now mention that the planet has 10 moons, but no possible correlation exists between Themis and S10 (Janus), since Janus lies very close to the outer edge of the rings. In 1966 Earth passed through the plane of Saturn's rings, so that they were viewed edge-on and were therefore not as dazzlingly bright as usual. A. Dollfus in France photographed the region near Saturn during the brief period of the "disappearance" of the rings, and discovered Janus.

During a period of around a month following the discovery, Janus was located again. However, because it was only possible to observe for a short time, and because Janus was nearly at the limit of photographic detectability, some uncertainty has remained about the orbital parameters.

For example, J.W. Fountain and S.M. Larson analyzed other photographs of Saturn during the 1966 passage and found many observations inconsistent with just one new satellite, while almost all were consistent with two new satellites. Indeed, separate images of two distinct satellite candidates were identified on the same plate in photographs taken Oct. 29 and Dec. 18, 1966. Fountain and Larson concluded that Saturn possesses at least eleven moons. Confirmation of S10 and S11 awaits the next Earth passage through the Saturn ring plane, which occurs later this year.

Jupiter

Jupiter, the giant planet of the solar system, has also had its share of new satellite predictions and observations. The principal survey for Jupiter satellites was made in 1938 by Seth Nicholson with the 100-inch telescope at Mt. Wilson. Nicholson photographed the area surrounding Jupiter down to a magnitude of 19.5, during which he found J10 (Lysithea) and J11 (Carme). (As a student, Nicholson had found J9 [Sinope] in 1914 and returning to the search in 1951 found J12 [Ananke].)

More recently, E. Bowell and L. Wilson noticed a pattern of orderly relations involving the orbital angular velocities of satellite groups in the solar system, and on that basis predicted in 1967 the existence of three new satellites, one each for Jupiter, Saturn and Uranus. This prompted E.K. Bigg in 1969 to study the decametric radio emission of Jupiter, which he believed was due to an undiscovered jovian satellite. Bigg concluded that observed periodic modulations indicated at least one and possibly two new jovian moons whose properties were commensurate with the predictions of Bowell and Wilson. However one year later, J.N. Douglas and F.A. Bozyan demonstrated that the modulation had lain in the instruments used, not nature.

This didn't end the search for new jovian satellites: in 1974 Charles T. Kowal discovered J13 (Leda) using the 48-inch Schmidt telescope at Palomar Observatory. Kowal was not satisfied with the observations however, and continued his search, discovering a probable fourteenth jovian satellite in October 1975. The identification of J14 is still tentative because the object has not been recovered in more recent photographic searches.

Mercury

The most recent detection of a satellite which later proved to be incorrect was by spacecraft in 1974. In March of that year Mariner 10 was flying past Mercury; on March 31 Lyle Broadfoot and Michael McElroy announced that Mariner's UV scanner had detected what they believed to be a mercurian satellite. The object appeared to revolve around Mercury in an eccentric orbit whose average radius was 15,000 miles. As Mariner receded from Mercury, the object appeared to diminish in size with increasing distance. A search for the satellite with Mariner's television camera was begun that same day.

On April 1, 1974 — one day later — it was announced in the newspapers that the detection of a mercurian moon had been erroneous. Mercury's "moon" was a star. The apparent orbital motion of the supposed satellite had been due to the motions of Mariner 10 and Mercury itself. With the speed of the modern mass media, the whole matter was settled in the newspapers over two days, and the subject never entered scientific literature.

Astronomers have roamed the solar system with telescopes and cameras for a long time. The search for new bodies in our solar system neighborhood continues, frequently turning up new objects, as the history of the last few years alone clearly shows. But mistakes will be made, for the development of any science requires researchers to push their equipment, their ideas, and their perceptions to the extreme limit. And naturally enough, the conclusions they reach are sometimes shown later to be faulty. But the general trend, despite occasional steps backward, is toward a broader and yet a more detailed understanding of nature and the universe, and the only safe prediction for the future of astronomical discovery is that we have a lot of surprises remaining in store for us.

David B. Kasle Univ. of Hawaii
Dale P. Cruikshank Honolulu, HI

Behind the Scenes

And The Winner Is...

A few months ago Robert Maas, AstroMedia's President, announced ASTRONOMY's monthly telescope drawing — with an Edmund Astroscan 2001 telescope as the prize — for those subscribers renewing their subscriptions promptly upon receiving their first renewal notice. We're pleased to announce the winner of the first telescope, Ronald Dietz of Fort Walton Beach, Florida. Mr. Dietz is a captain in the Air Force, and he writes: "I was thrilled to win the Astroscan...it's perfect for someone like me who lives in an apartment and can't easily set up a cumbersome apparatus." The picture he's sent shows him standing with his telescope overlooking the Gulf of Mexico.

You'll have your chance to win an Astroscan, too. Here's how it works: your first renewal notice will arrive two months before your ASTRONOMY subscription expires. Return the first notice within ten days and you're automatically eligible to win the Astroscan.

On the editorial side, we're expanding our services to you in another way. The free ads in Astro-Mart are now open to everybody, not just our subscribers. Our newsstand sales are now large enough that we want to include those readers.

Also just in case you haven't looked at Astro-Mart in a while, you'll notice there are a growing number of announcements of club meetings. We'd like to encourage that trend, so we're adding an announcements section at the end. A typical announcement might read as follows:

ANNOUNCEMENT — MILWAUKEE ASTRONOMICAL SOCIETY — meets 3rd Friday 8 p.m. each month Sept through May, Physics Building on UWM campus. Summer meetings at Observatory. Call Raymond E. Zit for info, 123-4567.

There it is: in just 29 words, help for both readers and astronomy clubs looking for each other.

Just one more short item: we have a limited number of "Voyager 1 Science Results Reprints" from the June 1 issue of **Science** that we'd like to offer to you at $2.50 each (price includes postage). This 80-page booklet with 14 color pictures contains the first scientific papers written by the

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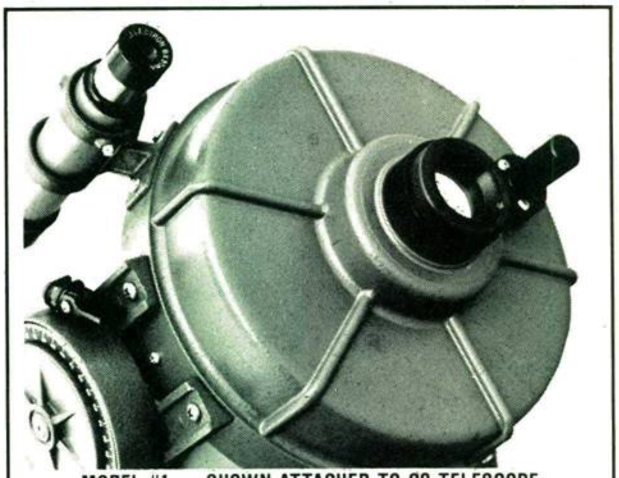
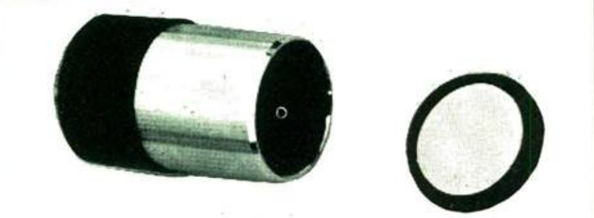


MODEL #1 — SHOWN ATTACHED TO C8 TELESCOPE



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Model #2 — $250.00

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- (F) 5461 — Mercury
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- (H) 5790 — Mercury
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Rejection Ratio — 461:1

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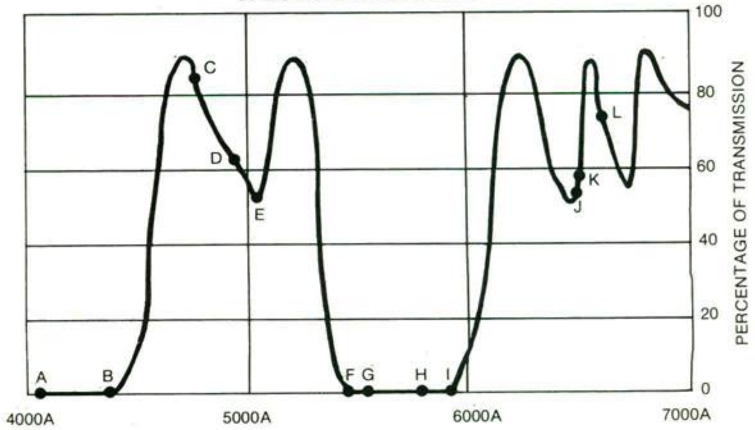

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Minimal Astronomy

by
Frithjof A. S. Sterrenburg

When you read most periodicals and books aimed at the astronomy enthusiast, you often get the impression that astronomy requires two things to make pursuing it worthwhile: clear dark skies and a telescope of at least 6″ aperture.

The United States is certainly "astronomer's country" in view of the wide range of moderately priced telescopes available and the relatively easy access to vast areas of country with good seeing. But even in the U.S., many people must be content with a small telescope and most don't have Californian skies. You may end up concluding that what I call "minimal" astronomy has little to offer, and in this you'd be completely wrong.

From an astronomical point of view, Holland, my native country, is far from ideal. Our population density ranks very high overall, and our physical elevation is one of the lowest anywhere. To cap things off, the climate must be one of the world's least inspiring. Even out in the countryside, there are few locations where some town, city, or highway doesn't bathe the horizon with glare. Moreover, haze frequently interferes with seeing conditions.

Some time ago I started a simple project to determine the limits of "minimal" astronomy, that is, a systematic examination of interesting astronomical objects under less-than-ideal conditions using a small refractor. My reasons for the project were twofold:

First, the observer's literature always states that a small refractor can show quite a lot, but the list of objects then given is usually fairly short.

Second, I had recently salvaged a 60 mm refractor with a 900 mm focal length from an attic, where it had stood neglected for years. I had intended to use it as a guidescope on a large reflector, but since the equatorial mounting was good, I decided a complete overhaul should be carried out first. The instrument was a Mayflower 60 mm refractor, similar to many other such instruments sold in the U.S. I wanted to test the telescope to the limit under my unfavorable skies.

The eyepieces used were a high quality 40 mm "monochromatic", a 20 mm Kellner, and a 9 mm orthoscopic, all from various sources. Occasionally, I used a Barlow lens of professional quality. I rebuilt the finder (a good 30 mm aperture achromat) to take a zenith prism.

My observations were made in a rural area with good seeing (for Dutch conditions). With the naked eye, stars to magnitude 5.0 (Eta UMi) were usually visible when near the zenith. Under the same conditions, the Milky Way can be seen down to about 20° above the horizon. But the number of nights with fair or better seeing is very limited. When the Moon isn't lighting up the skies, haze, clouds, rain, or almost perpetual winds may spoil the view. If you add in factors such as business and family life, you can end up with observing sessions but once a month.

(My personal qualifications for doing this observing program were nothing special, but I do have good eyesight and am used to looking for difficult and dim objects.)

Naturally, the craters on the Moon, the rings of Saturn, moons of Jupiter, many clusters and double stars are visible in a small telescope. But stating these objects are "visible" gives no idea of the astonishing amount of detail that can sometimes be seen. Because lunar observations could fill a book by themselves and since Mars wasn't in a favorable position during the program, let's consider three other solar system objects as seen through a 60 mm refractor.

The Sun One safe and optically sound method of observing the Sun uses a high quality, visually-safe solar filter placed over the objective. With such a filter, and 50 to 100x, the amount of detail which can be seen in sunspots is considerable. The umbra and penumbra are clearly distinguishable, so that the appearance is somewhat crater-like. Jagged edges and "bridges" in the photosphere can also be seen.

Quite surprisingly, a 60 mm refractor with a good solar filter can show the granulations of the Sun's surface. The literature often claims that you need at least 4″ of aperture. I found that it was detectable at 100x, though I had to look carefully during moments of excellent seeing.

Jupiter If the objective is well-corrected, powers as high as 150x or more can be used. The rotational flattening and two main equatorial belts are immediately obvious even at 45x, but with steady conditions, higher powers will reveal more surface banding. Remember that contrast will be low. The colors are pastel rather than the saturated hues you may expect from seeing some color photographs.

Saturn Even with the lowest power, the rings are obvious. (This

Left: Although its integrated magnitude puts it within naked-eye limits, M-33 can definitely be hard to find. You'll do best if you scan slowly past its location using low powers, for this will bring the tenuous glow to your attention. Photo by Evered Kreimer. Above: M-57, the renowned Ring Nebula, is a thin shell of gas thrown off from the 15th magnitude star in the center of the ring and made to fluoresce by its vigorous ultraviolet radiation. Though it appears clearly here in the photo, you'll need at least a 12″ scope to pick it up visually. Photo by Leo Henzl.

year is an exception since the rings are seen about edge-on.) Even Cassini's division can be glimpsed under good seeing, as can the shadow of the ring on the planet. Saturn's moon Titan (magnitude 8.5 at opposition) is easy. For planetary observations in general, I've found that good conditions mean absence of scintillation ("twinkling") more than a jet-black, transparent sky.

You'll find that the number of double and multiple stars you can resolve into their component stars is very large indeed. Two of the more attractive objects are the following:

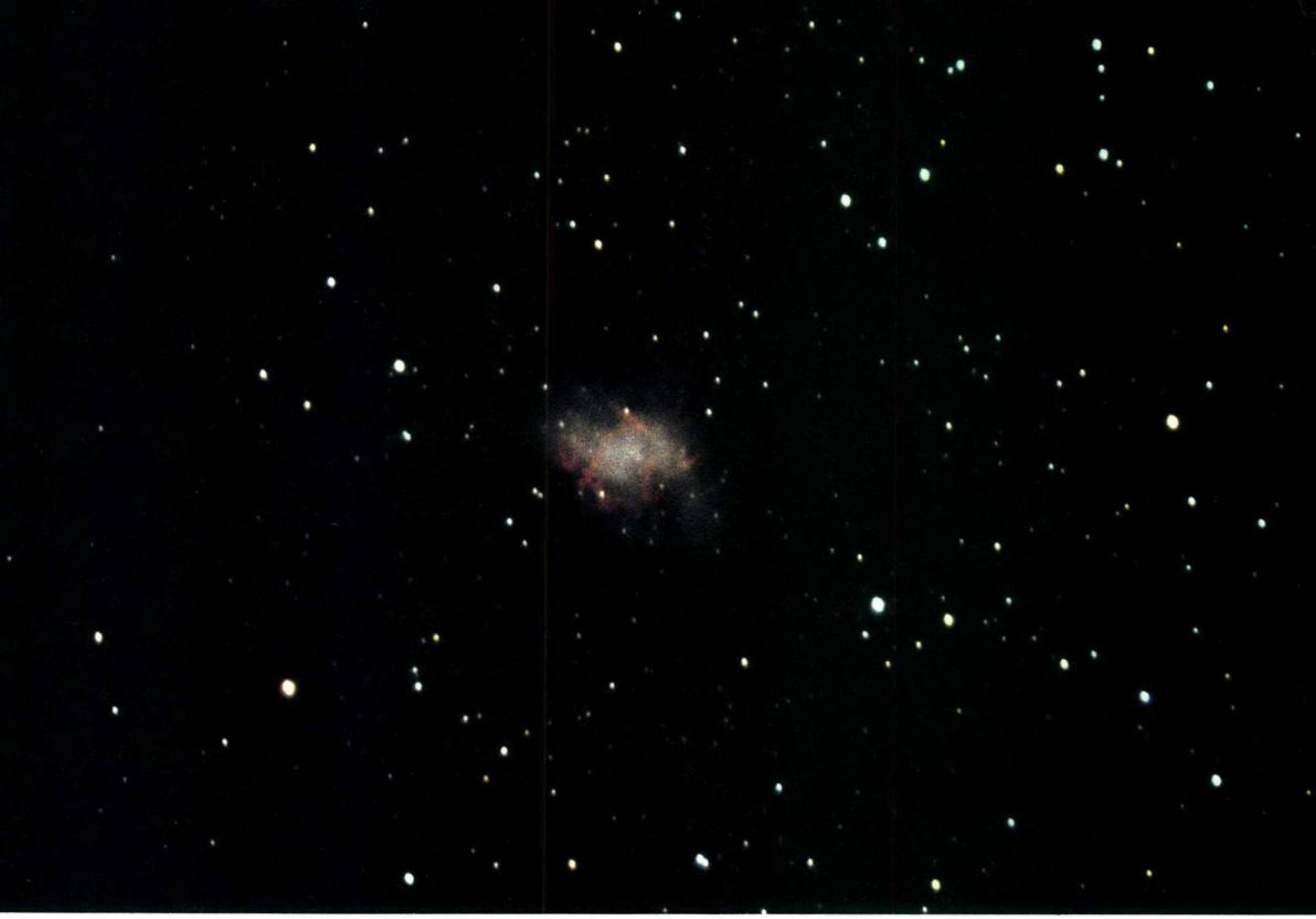
Alpha UMi (Polaris) This pair is an optical double, that is, a chance alignment on the sky, not a physically associated group. The two stars are widely separated (18.3 arc seconds) and there's a large magnitude difference (2.1 and 9.0), making the pair a good test of your eyepiece's freedom from internal reflections and flare. If your eyepieces are poor, you may have trouble picking out the companion in the glare of the primary.

Epsilon Lyrae Most observers are led to believe that a 60 mm objective will show only two stars instead of the famous "double double." Theoretically, a 60 mm refractor should resolve stars about 2″ apart, provided their magnitudes aren't too dissimilar. The separations of the pairs Epsilon^1 and Epsilon^2 are 2.8″ and 2.3″, so the latter pair begins to approach the theoretical limit for a 60 mm glass. I had a very pleasant surprise, therefore, in seeing all four stars, even at 45x. At 100x and with the Moon near first quarter, I didn't have the slightest difficulty in splitting both pairs. The stars were totally separate, with no tendency for the images to overlap and form a "raindrop" shape, even for the closer pair. The difference in brightness for the Epsilon^1 system seemed more than the published magnitudes which are 6.0 and 5.1. (If your 60 mm telescope splits the closer pair, both your eye and your telescope leave little to be desired, though the test was easier than I expected.)

M-57 The renowned Ring Nebula in Lyra has a visual magnitude of 9.1 and should therefore be easily visible. On a clear night, but with the Moon 6 days old, it was even visible as a ring — a very pale wisp of smoke with a darker center. Seeing this was so surprising to me that I had to verify it repeatedly. One source in the literature claims it takes 8″ aperture or more to see the ring shape well. This now looks a bit overstated, but to get the results I did, Lyra must be near the zenith.

M-1 I expected to find the Crab Nebula readily with a 60 mm scope in view of its magnitude of 8.5. However, under reasonably good conditions, you should be able to discern much more than a faint glow. I saw it clearly with 45x, its outline fairly well-defined and clearly irregular, the center being more luminous. Coarse serrations tattered the periphery, and it looked blotchy, though this was more difficult to see.

M-33 In winding up this short list of objects, I took a look at the spiral galaxy in Triangulum. The literature all agrees that it's rather hard to make out because its surface brightness is very low. One source stated that with a 4″ at 40x, it resembles a "faint cloud"; in other books a fast system (f/4.5 or so) is said to be necessary. Certainly, a 60 mm f/15 telescope doesn't reveal a brilliant spiral, but at 25x, M-33 appears a fairly large faint object



6500 light-years away, a massive star ended one phase of its evolution with a titanic bang that blew off its outer layers into space. Over the 900+ years since, the gases have been rushing outwards at velocities that have now expanded the cloud to a rough diameter of 15 light-years. While your small scope won't show the tendrils of gas snaking through the cloud, you will see the overall asymmetry. Photo by Bill Iburg.

whose outline is roundish although the margin isn't well-defined.

Articles on the smallest size of telescopes always state that despite their modest aperture, they can give much satisfaction. Unfortunately, the literature usually mentions only a few of the easiest objects and warns that much greater aperture is necessary to see more. This isn't very helpful for the beginner and therefore I've tried to determine the limits of such a small instrument under conditions that were realistic rather than exceptional.

The small refractor, provided it is of excellent quality, shouldn't be underestimated. In fact, compared to the naked eye, using such a telescope probably gives you the greatest relative increase in penetration of the universe you'll ever attain. Should you want to improve as much on the 60 mm refractor as that instrument improves on your unaided eye, you'd need an aperture of 12″.

The 2.4″ Refractor

It's unfortunate, but the 2.4″ refractor may be on its last legs as a commonly used instrument. Under the present yen to dollar conversion rate, Japanese-made refractors have effectively priced themselves off the market. Today, four-inch reflecting telescopes are becoming the preferred instrument for the beginner. With more light grasp and greater resolving power, a 4″ reflector can certainly do everything a 2.4″ refractor can.

Most small refractors, even of good quality, often have two shortcomings that can be altered at reasonable cost and which provide much greater ease in operation:

1.) The "straight" finder is very awkward to use near the zenith, precisely where you'll be doing most starwatching. Buy the best right-angle finder you can afford, or if you can work metal, modify the finder to take a zenith prism or star diagonal.

2.) The commonest low power eye piece (giving 40x usually) is too great a magnification. Get an eyepiece giving about 25x (which will have a focal length of about 35 mm), and be sure to test the eyepiece in use.

But remember, the best equipment in the world is wasted if you, the observer, aren't doing all you can to be prepared. Let your eyes dark-adapt fully. Don't smoke while you're observing (nicotine hinders dark-adaption, apart from whatever else it'll do to you), and take care to cover your observing eye if passing cars' headlights are unavoidable at the site. A lightweight dark cloth such as used by view-camera photographers will exclude extraneous light much better than a cap or screen on the eyepiece. Finally, relax and be comfortable.

Although large apertures and pitch-black skies are naturally better, nevertheless the small "trophies" I collected during my minimal observing project were more rewarding because of the self-imposed instrumental restrictions. With care and patience, and even under somewhat murky Dutch skies, I found the 60 mm small telescope had far more to offer than most introductory articles, even some advanced observer's guides, would suggest.

Frithjof Sterrenburg is a science writer living in the Netherlands. His amateur astronomical interests are partially a result of his professional career in optical instrument design.

CELESTRON C11 TELESCOPE

Celestron has announced a forthcoming new 11 inch member to their telescope line. **Astro-Engineering** is now accepting reservations for this scope that is soon to be in great demand. Although full scale production is not expected until around the end of the year; this should not detour you from getting your name on our reservation list. We will keep you informed of any information that becomes available to us (Prices, Optical system, Delivery date, etc.). Send $5.00 (applied towards purchase) and your name & address to receive your reservation number and future progress reports.(no obligation)

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Meade Instruments has just announced their Research Series 8", 10", 12½" Reflecting Telescopes. We firmly believe that these three new Newtonian instruments will shake the astronomy market with strong approval. Further information can be gained in Bulletin 1200. (included with our catalog package)

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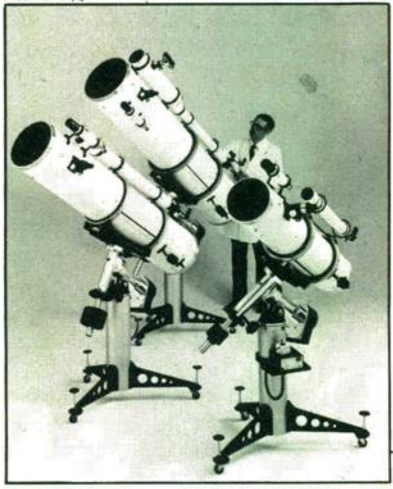
MF-3 1¼" Thread-in Moon Filter $29.95



→ Research Series: 8",10",12½"

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All Celestron products we sell are taken directly from the Celestron factory to our Torrance facility (approx. 1 mile). At this time every product is fully inspected for mechanical and optical performance. Upon passing inspection the equipment is taken directly to United Parcel Service for shipment. This eliminates multiple shipping encountered by most other dealers. We maintain the same policy with Meade Instruments as we do with Celestron. Meade inspection is done at our Costa Mesa Headquarters & Showroom. We are in the progress of implementing a computer system which will greatly decrease the time needed to process orders; this will result in faster shipping.

CELESTRON 14 TELESCOPE Base Price .... A-E's old price

The base-price Celestron 14 is a complete working telescope and includes optical tube assembly, visual back, giant 2" ID star diagonal (with 1¼ adaptor), finder scope, fork mount, setting circles, electric slow motions in RA and Dec., electric clock drive, clock drive cord, illuminator/map light, piggyback camera mount, Tele-Extender, T-adaptor, counterweight set, lens cap, carrying cases and instruction manual. Also included are four 1¼" OD oculars: a 6mm (Or) - 650X, a 12mm (K) - 325X, a 25mm (K) - 155X and a 40mm (K) - 100X.

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The base-price Celestron 8 is a complete working telescope and includes optical tube assembly, visual back, star diagonal, 25mm ocular (1¼" OD, 80X), 40mm ocular (1¼" OD, 50X), finder scope, fork mount, setting circles, manual slow motions, electric clock drive, clock drive cord, lens cap, carrying case and instruction manual.

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Ha-3 Hydrogen-alpha 6563, Thread-in 1¼"	$149.95
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All three filters	$369.95

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- Our Nebulae filter is computer designed to specifically meet the needs for both visual and photographic observations.
- Clear optical aperture: 23mm (Model 3)

NF-1—.96" Thread-in filter	**$29.95**
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NF-4—Series VI drop-in	**$79.95**

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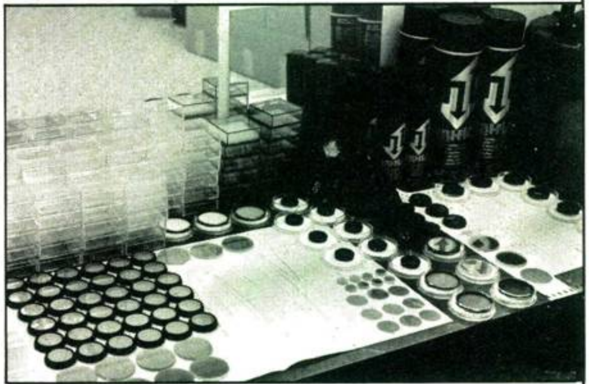

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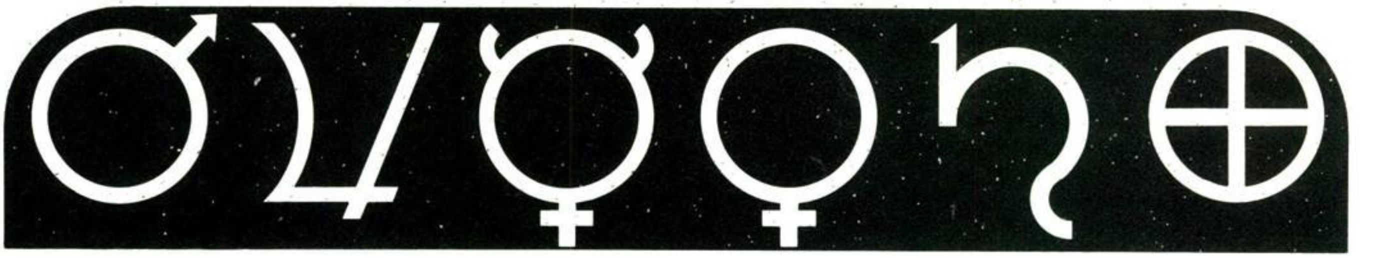


Don't Miss the Perseids

It almost seems as if the Sun is devouring its children: Jupiter hides in the solar glare until late in the month, and Saturn and Venus both disappear into it. Of the remaining five planets (excluding the one we're standing on), only two (Mars and Mercury) are visible easily to the naked eye, and both are in the morning sky.

September Previews

6	Full Moon: lunar eclipse
10	Saturn in conjunction with Sun
12	Occultation of Aldebaran
13	Last quarter Moon; Mercury at superior conjunction
15	Moon 5° south of Mars
18	Moon 2° south of Jupiter
21	New Moon
23	Equinox, beginning of Autumn
26	Jupiter-Regulus conjunction
28	First quarter Moon

As a glance over the above shows, there'll be some conjunctions in the morning skies — fine photo material!

Aldebaran's occultation will be seen by most of the U.S., but by little of Canada except southern Ontario and southwestern Quebec. The northern limit for U.S. observers runs from southern California northeastwards across Colorado and Nebraska to central Wisconsin, then roughly eastward over Lakes Michigan and Huron (through Georgian Bay) and passing through Montreal.

The Moon's phase (a day before last quarter) means that the disappearance will be on the bright limb, with reappearance happening from behind the unlit half of the Moon.

Mercury

On the heels of its appearance in the western sky last month, this swift little planet puts on a brief show in the eastern skies before sunrise.

In the diagram on page 42, you'll see the path it takes during August and the beginning of September. As usual, the time is a half hour before sunrise, and the observer's latitude is assumed to be 40° north.

It's rather easy to find the planet, though you'll need a viewing place that gives you a low horizon; a hilltop may be ideal. Face towards the east-northeast, and look for a dimmish point of light low above the horizon.

Mercury's orbital motion is currently taking it out to the west of the Sun. The time of farthest separation is called greatest western elongation; the actual date is early on the 19th (UT), when its angular distance from the Sun will be 19°.

On the mornings of the 19th and 20th, you'll see Mercury, a slim crescent Moon, and Mars all lined up in that order above the horizon. If you have a normal or wide-angle lens for your camera, try for a shot with all three objects in it. (See also the Jupiter section for details about another conjunction on the 30th.)

Those with telescopes will be able to pick out the changes in Mercury's apparent phase as it passes from crescent (before maximum elongation) through half-lit to almost round (late in the month). Your lower-power eyepieces will work best, because they'll magnify the atmospheric distortions least.

Venus

Venus is virtually out of view this month as it's too close to the Sun to be seen easily. Starting in September, Venus will become an "evening star" as it re-appears to the east of the Sun after sunset.

Mars

Mars moves rapidly out of Taurus and into Gemini, passing about 15° north of Betelgeuse during the first week of August. The planet rises about 3 a.m. daylight time, but won't become prominent until an hour or so afterwards. Thirty minutes before sunrise on the first of August, it'll be 30° high and almost due east. By the end of the month, at this same time its elevation will be 40° and its direction will have shifted to just south of east.

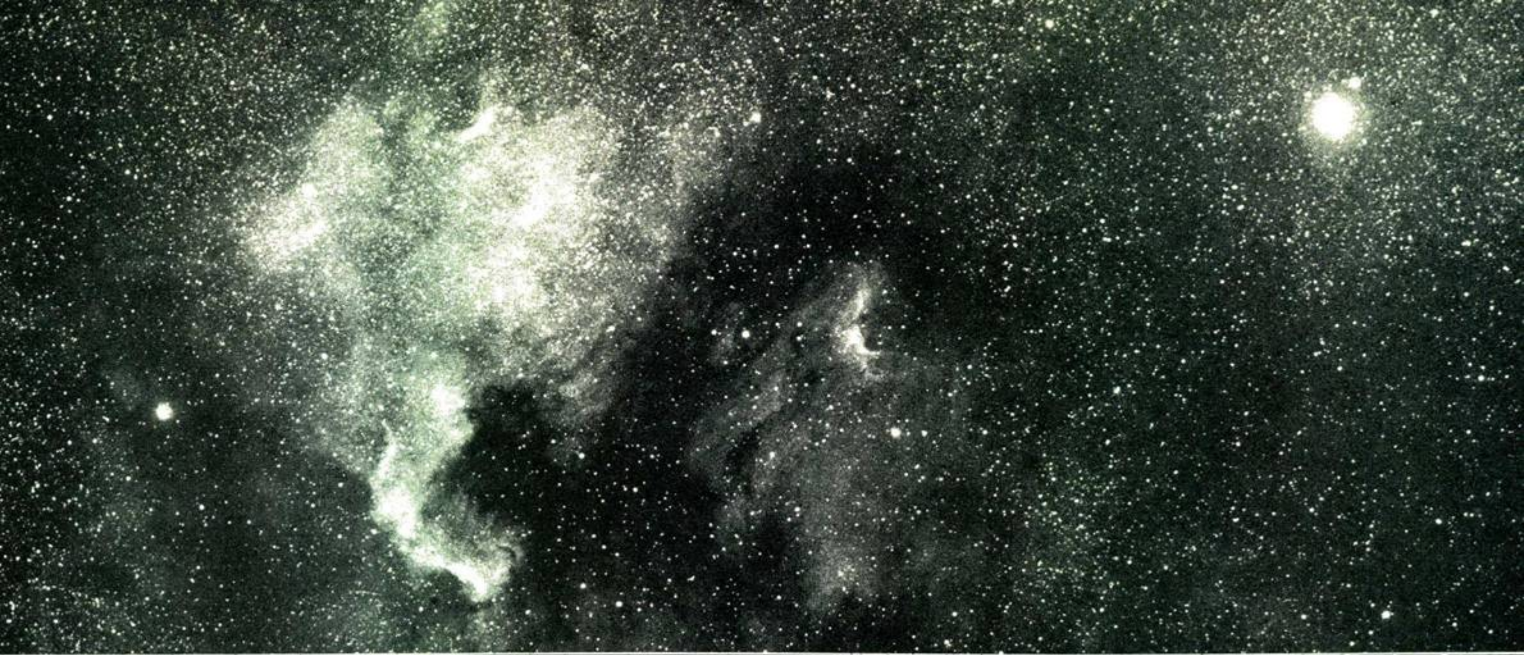
On the morning of the 18th, the Moon, halfway between last quarter and new, will be 5° to the south of magnitude +1.5 Mars. Binoculars will show the two together, and while you're at it, try for a photo framing the two together.

Mars will gain only a third of a second of arc in size over the course of the month — from 4.6 to 4.9 arc seconds — not very much! Even though the planet hasn't a lot to show right now, start observing anyway so that later in the year, when Mars is closer and larger, your practiced eye will see more detail.

Jupiter

Jupiter passes half a degree north of the Sun on the 13th, thus marking conjunction. The planet will be invisible then, but by the end of the month watch for it rising just before the Sun.

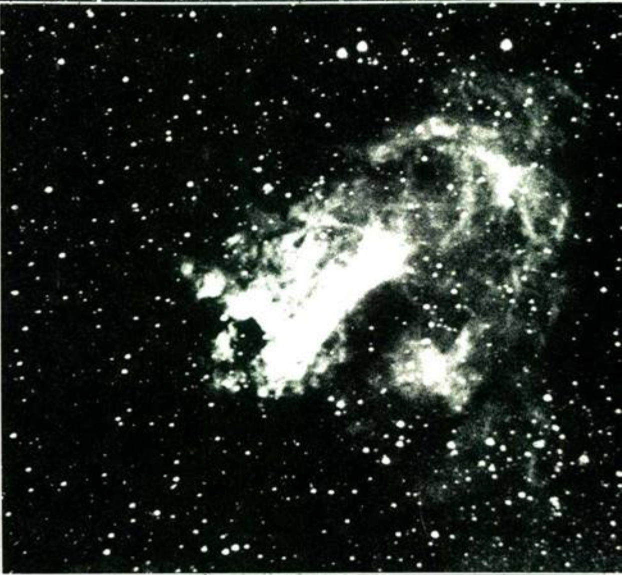
In the diagram of Mercury's motions on page 42, we've also plotted the

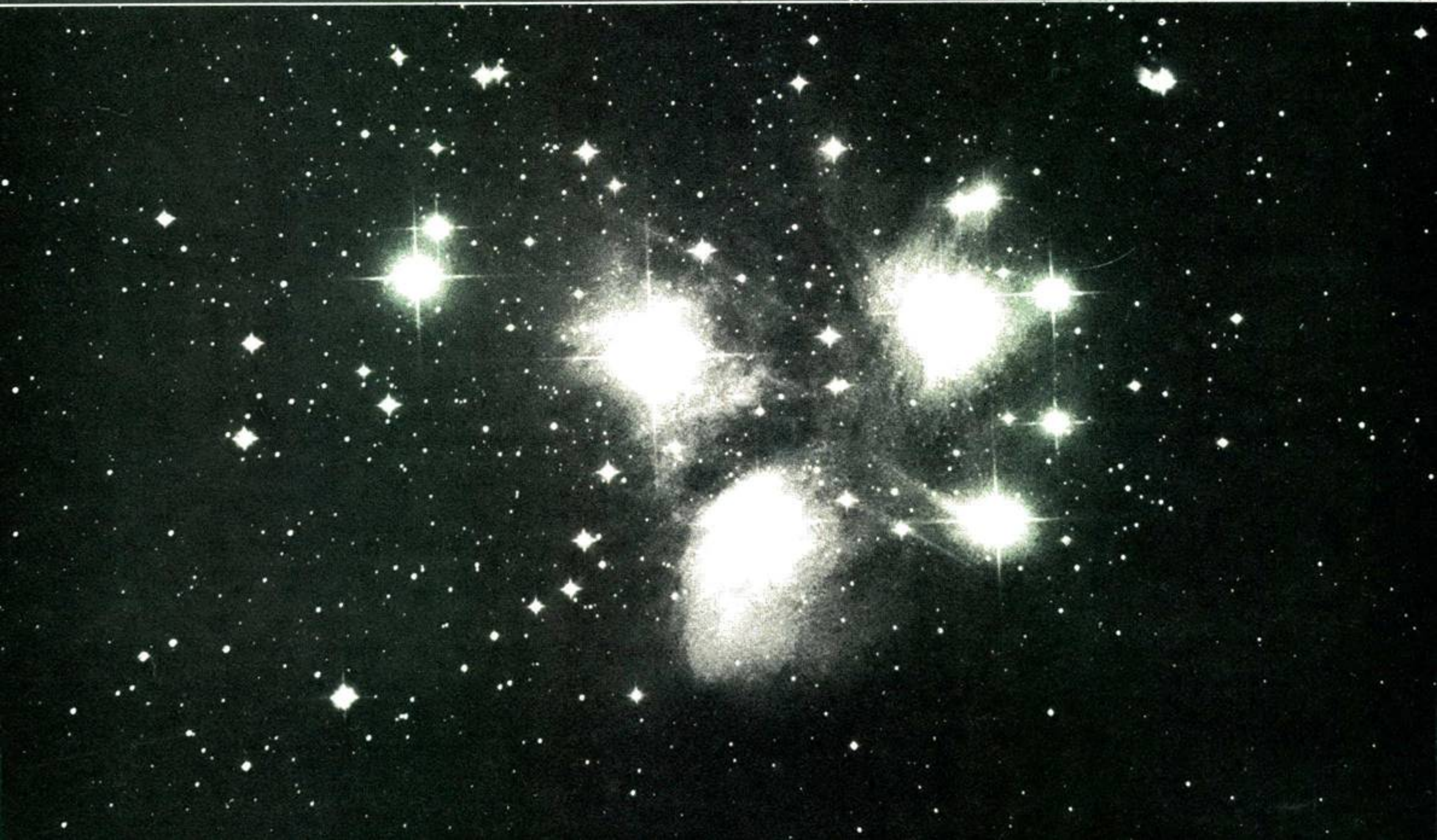


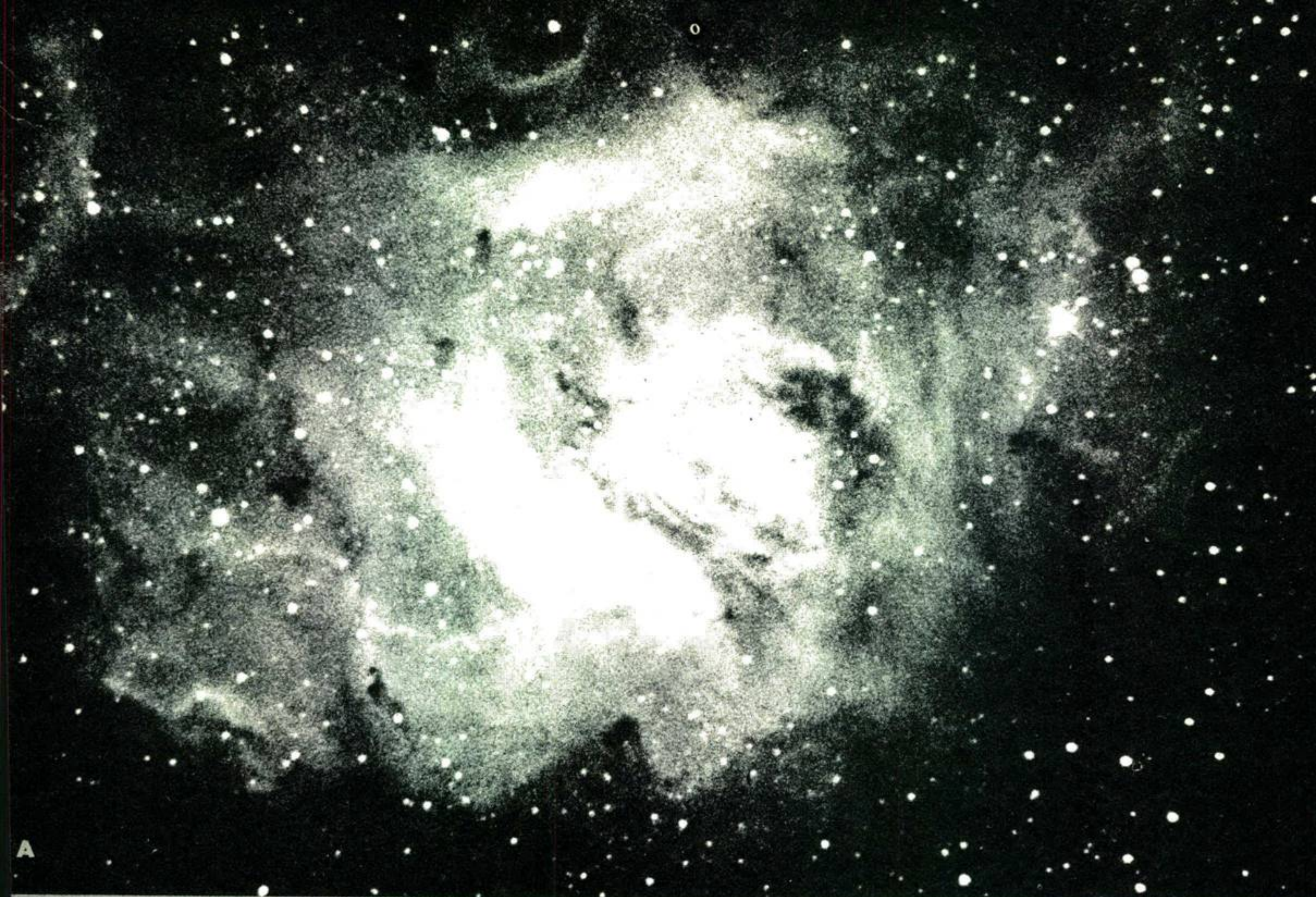
Deep Sky Portfolio

Many astrophotographers today work in color, and there's no doubt that the results can be superb. Yet black and white is capable of equally stunning results when a little thought and care go into the work. To highlight this, and perhaps to stimulate your efforts, Sky Almanac this month is presenting a showcase of fine deep-sky photography.

Above: Hugo Bilkisdorf used his 6.3" (160 mm) f/3.3 Maksutov camera for this photo of NGC-7000 (the North America Nebula) and IC-5067 (the Pelican Nebula). Film was 103a-E (red-sensitive) and the exposure lasted 30 minutes. **Right:** August Schug also used 103a-E for half an hour to capture M-17, the Omega Nebula. The telescope was a 12½" f/4.8 Newtonian. **Below:** The familiar Pleiades. Robert Provin stopped his 6" f/5 to f/6 and exposed 103a-O (blue-sensitive emulsion) for 30 minutes.







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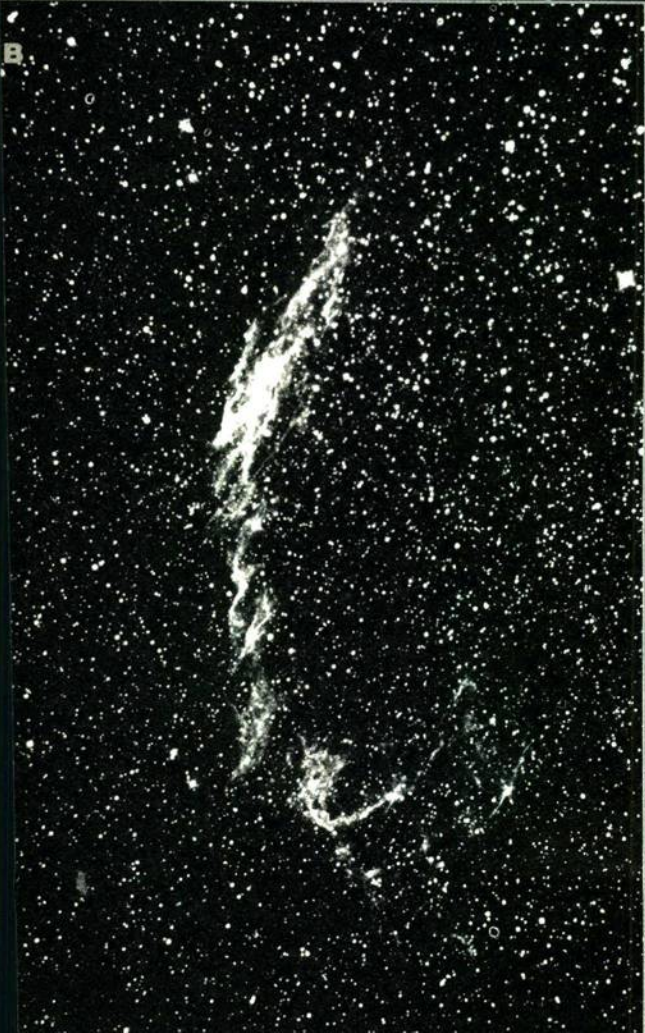
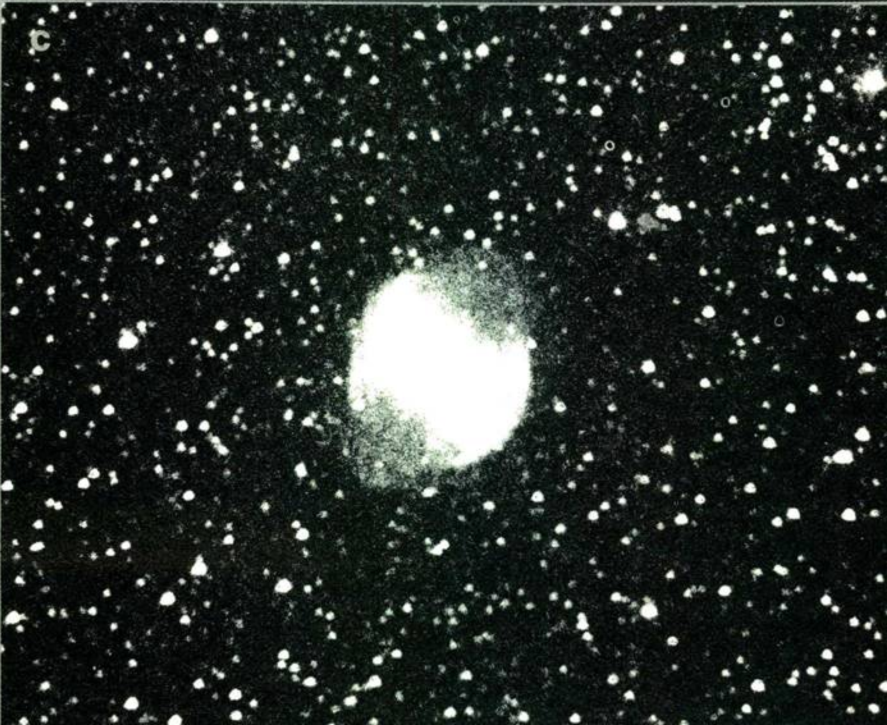


B

A: The filmy wraiths of the Lagoon Nebula (M-8). Photo by August Schug with same equipment as on previous page. **B:** NGC-6992, the eastern part of the Veil Nebula. Robert Provin photo. **C:** M-27, the Dumbbell Nebula, by August Schug. **D:** Howard McCallon used a 12½" f/5.6 scope and 103a-E for 18 minutes to get the Horsehead Nebula in Orion. **E & F:** Jack Newton's before and after photos show a supernova in M-100. 12½" f/4.6 scope with 103a-F for 20 minutes. **G:** M-81 (top) and M-82 were both caught by Walter Hamler's 8" f/5 scope. He used 103a-F for 20 minutes. **H:** The Eagle Nebula (M-16) is about 8000 light-years away in Serpens. August Schug photo.



C

D

G

E

F

H

September's Pre-dawn Lunar Eclipse

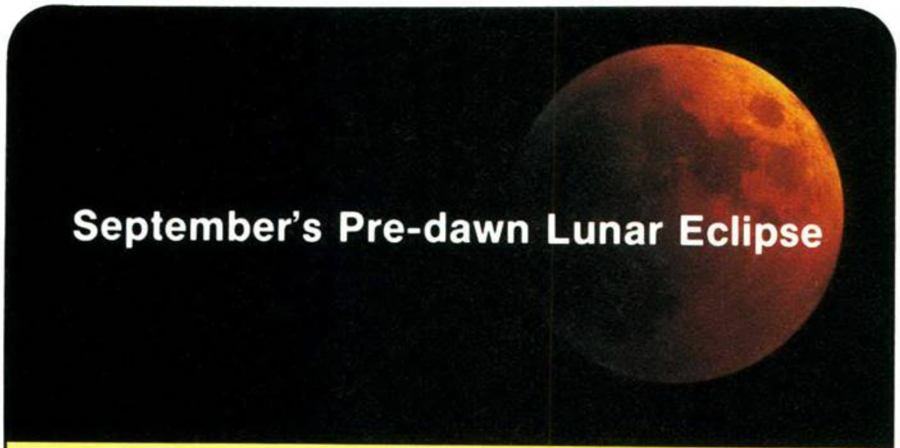


Photo by Gary L. Napier

Eclipse buffs will have the opportunity to add another event to their lists on Thursday morning, September 6th, as the Moon slips slowly into the Earth's shadow. This is the first lunar eclipse visible from this hemisphere since May 25, 1975, and is the last visible here until July 6, 1982.

Not all North American observers will see the entire event, since the eclipse begins only two hours before sunrise on the east coast. The beginning of totality is visible from all of North America except the northeastern part where the Moon will have set already; the end can be seen from the western half of the continent.

The penumbral phase of the eclipse begins at 08:21 UT (04:21 EDT); the umbral (or total) part starts at 09:18 UT (05:18 EDT). Unfortunately for easterners, morning twilight begins at 04:58 EDT and the Moon enters wholly into the Earth's shadow at 06:32 EDT. Within a few minutes of this time the Moon will set as the Sun rises.

The midwestern and western U.S. will experience sunrise one to three hours later giving observers in these regions enough time to see the umbral (total) phase in its entirety.

The Moon will be wholly eclipsed for nearly 46 minutes. At 11:18 UT the total phase ends, and the Moon leaves the umbra completely at 12:31 UT. The end of the penumbral phase at 13:29 UT marks the finish of the complete event, more than five hours after its commencement.

Even though the eastern part of the country won't see the entire eclipse, they will see the rather rare sight of a coppery eclipsed Moon framed against the dark blue sky of morning twilight. Some observers will see the Moon setting in total eclipse — a breathtaking sight. Midwesterners will see more of the event because the Moon doesn't set until after the total phase is over. In a nutshell, the situation is this: the farther west you live, the more of the eclipse you get to see before the Moon dips below your horizon.

What can you do during the eclipse? You ought to consider just sitting back and watching the view with binoculars or a low-power telescope: simple observations can be the most enjoyable ones at times.

You may want to take some photographs as a record; if so, it's very easy to do. Shooting through a telescope or using a telephoto lens (preferably 200 mm or longer) with a 35 mm camera is almost ideal. Choose a focal length that gives you a full-disk image.

Pick a relatively fast film as some eclipses have been very dark. Your exposure times will vary during the eclipse, but as a guide, the uneclipsed Moon comes out well at 1/250 second at f/8 on 100 ASA film.

The onset of the penumbral phase is usually undetectable by eye, but may be noticeable on film. As the eclipse develops, try to judge how bright it is and adjust your exposures accordingly. At mid-totality in a dark eclipse you may find that 2-6 seconds' exposure is necessary at f/2.8, while in a bright eclipse, a half-second might be sufficient. Follow the old rule: bracket your exposures.

If you want, you can take a different sort of photo using your normal or wide-angle lens. Put your camera on a tripod and set the lens at f/16. Place the Moon toward the left-hand side of your viewfinder, open the shutter, and lock it. As the Moon moves across your film, it will record as a streak that changes color and brightness as the eclipse progresses. Or try this: set up the camera as before, but use its double exposure mechanism to take a series of shots (say at five minute intervals) showing the eclipse, all on one frame.

Between photos try out the Danjon scale for estimating the darkness of lunar eclipses. Developed by the French astronomer Andre Danjon, the scale is used internationally. A very dark eclipse, with the Moon practically invisible, gets a rating of 0. A dark grey or brownish one, in which lunar details are discernable only with difficulty, gets a score of 1. Deep red or rust colored eclipses, with the central part of the umbra very dark and the outer edge relatively bright, rate 2. Brick red ones, with a bright grey or yellow rim to the Earth's shadow, are recorded as 3. And very bright coppery or orange eclipses with a bluish edge to the Earth's shadow, are rated as 4. The scale should be used with the naked eye and without optical aids.

Good luck and happy eclipse!

-- Dan Koehler

Lunar Phases

First quarter: August 1 at 5^h57^m UT, in Libra, and August 30 at 18^h 09^m, in Ophiuchus. Full Moon: August 8 at 3^h21^m, in Aquarius. Last quarter: August 14 at 19^h02^m in Taurus. New Moon: August 22 at 17^h10^m, in Leo. Perigee: August 8th at 19^h; apogee on August 23 at 7^h.

course taken by Jupiter. As you can see, on the morning of the 30th there'll be a conjunction of these two. Mercury's brightness then will be -1.0, Jupiter's -1.3. The sky will be bright and the planets very low, so pick a suitable place and use binoculars or a telescope with a low-power eyepiece.

Saturn

If you've wanted to get a look at Saturn, do it now: on the 1st of August, Saturn will be about 12° high half an hour after sunset. By the 15th, this'll be only 5°, and shortly thereafter the ringed planet disappears into the Sun's blaze of light.

Uranus

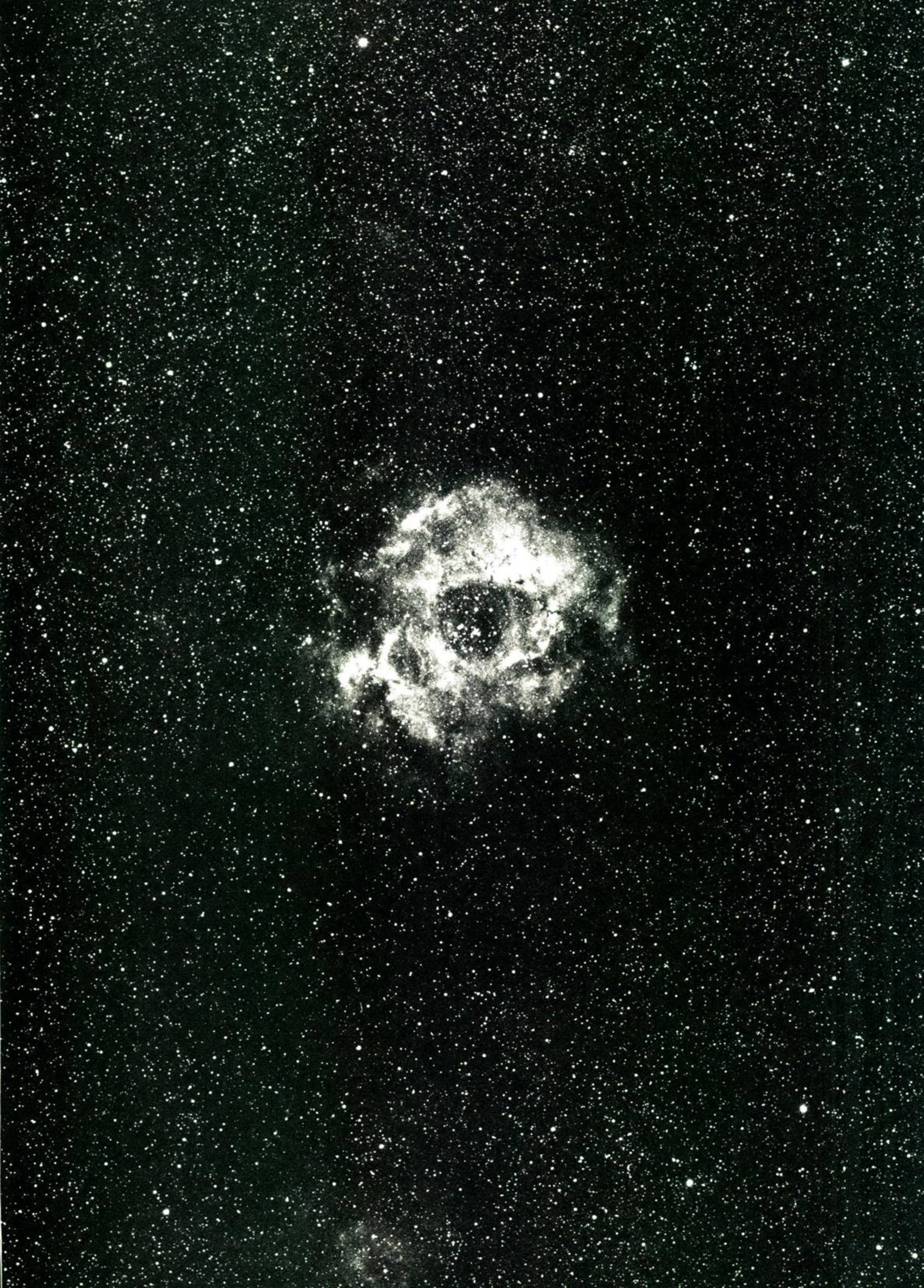
Having finished the small retrograde (westward) loop it's been making, Uranus now begins to move directly away from the 3rd magnitude star Zubenelgenubi. Better known as Alpha (α) Librae, it is the westernmost of the four stars in Libra indicated on the Star Dome. To locate Uranus, place the star at the western edge of a low-power field, either binocular or (preferably) telescope. Uranus will have a disk measuring 3.6 seconds of arc and is at magnitude 5.8. What little motion it has will be towards the east-southeast.

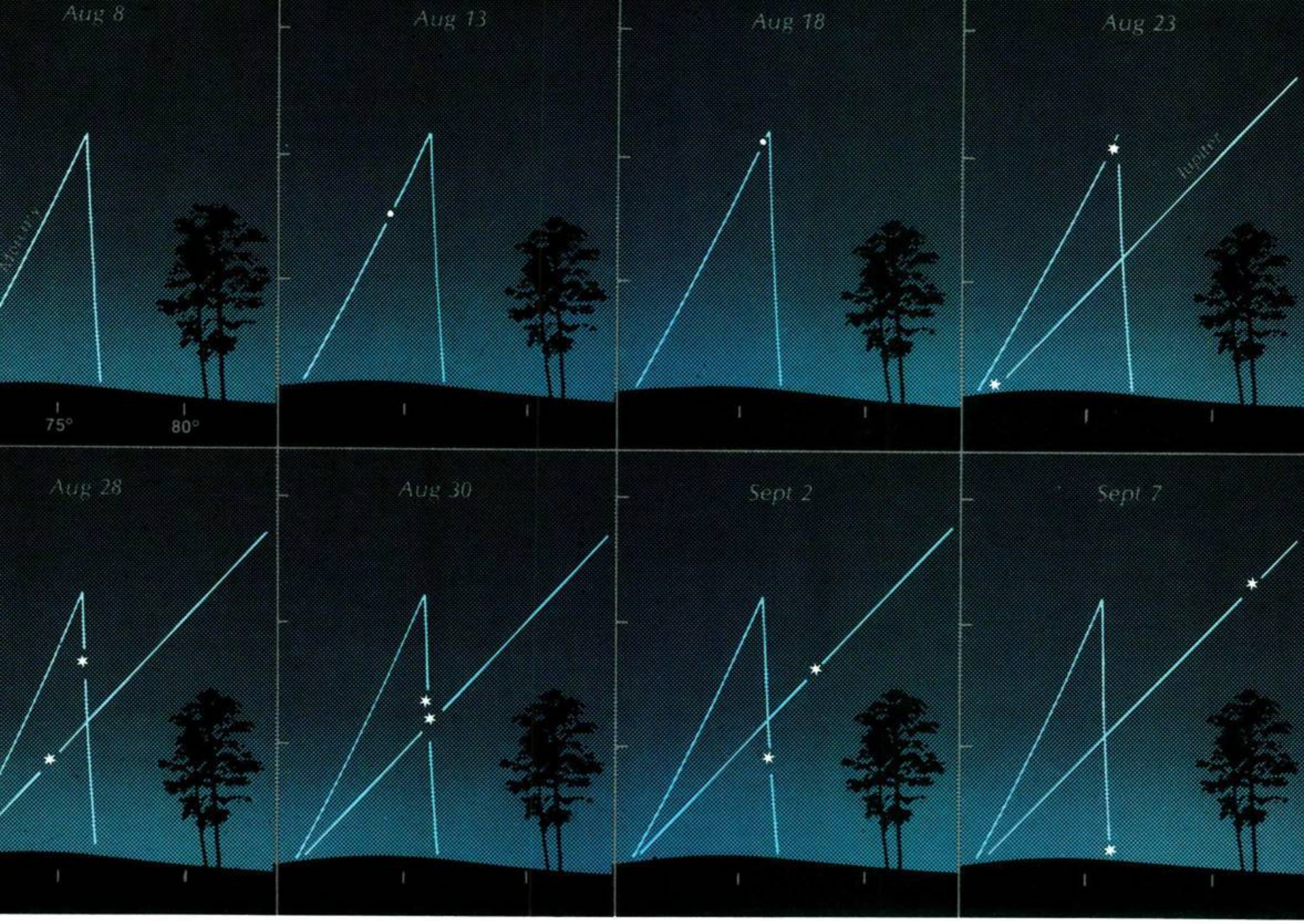
Neptune

Ever since April, Neptune has been moving westward away from the 4th magnitude star Xi (ξ) Ophiuchi. At the end of August it slows to a halt, 3° from the star. But resuming eastward motion in September, by the end of the year it will be back close to Xi, having regained in 3½ months what it lost over five.

Finding the planet means using a telescope to look for the "star" with a visible disk. You *can* locate it by watching for the moving spot of light in binoculars, but that requires a lot of tedious checking. On the 15th it'll have a disk 2.5 seconds of arc across, and as noted in Planet Finder, a magnitude of 7.7.

Hugo Blikisdorf's Maksutov (details on page 37) was used to produce this fine vista of the Rosette Nebula, NGC-2237. Clouds of ionized hydrogen like this photograph best with red-sensitive emulsions like 103a-E or F; reflection nebulae like that embedded in the Pleiades come out when shot with the blue-sensitive films like the old 103a-O or the newer IIa-O.





Mercury's (and later Jupiter's) positions in the morning sky are shown here for several dates. Note the conjunction on the morning of the 30th. The time is 30 minutes before sunrise and the latitude is taken to be 40° north.

Photo Tips

If you're planning to send us one or more of your latest photos, here are a few tips to remember:

1. Please send prints or slides only, no negatives.
2. Don't send silk-surfaced or textured papers — we can use only glossy.
3. Please, please print your name and address on *each* item sent.
4. Don't overwhelm us; send only your best ones.

Universal Time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times given in Sky Almanac are in UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska and Hawaii, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then the time in EDT would be 11 p.m. June 6. Likewise, 03:00 UT on Sept. 2 becomes, in PDT, 8 p.m. on Sept. 1.

Asteroids

Pallas, the second asteroid discovered but the dimmest of the "big four" (Ceres, Pallas, Juno, and Vesta), will be at opposition to the Sun on August 17th. Its path during August slices southwestwards through the northwest corner of the little constellation Equuleus. At the time of opposition, magnitude 9.1 Pallas will be less than 2° north of 4.8 magnitude Gamma (γ) Equulei.

Ceres (mag. 7.6) will be at $1^h30^m58.7^s$, -4°52′35.7″ (1950 coordinates) on the 15th of August. Pallas: $21^h08^m50.3^s$, +11°46′48.3″ (1950). Juno is too close to the Sun to be seen. Vesta (mag. 7.0): $2^h58^m55.5^s$, +8°27′02.1″ (1950).

Meteors

The big activity this month is the famous Perseid meteor shower. This is the best-watched of all meteor showers, probably due to the time of year, and a fine treat at the end of summer.

In Sky Almanac for last August, we gave some hints on ways to increase your meteor-observing fun, and so won't repeat them here. But whether you go about it in an all-out way or just sit there and look, there's no doubt that watching for Perseids is a very pleasant way to wind up a night of sky gazing.

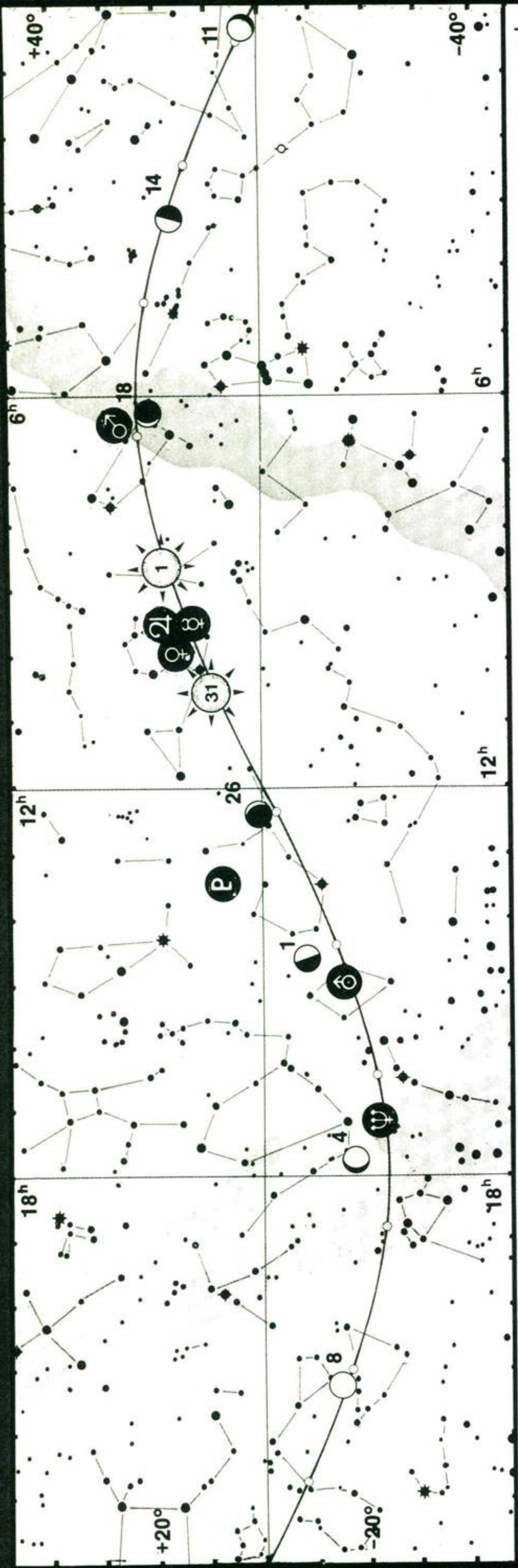
For this year's shower, the maximum comes on the 12th at 17^h UT. Since this is late morning or early afternoon in North America, you'll have to catch them before maximum (on the night of the 11th-12th) or just after (night of 12th-13th).

The drawback this year is the Moon: it'll be at last quarter on the 14th. When the Moon's up during a meteor shower only the brightest stand out, and if you plan to take pictures (see this month's Photography in Astronomy), you'll find that your exposures are severely limited by sky fogging.

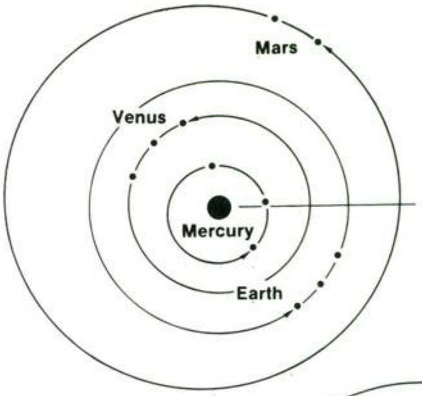
The radiant point (that place on the sky where the meteors appear to come from) is located near the Perseus-Cassiopeia border, and rises early in the evening. Because of this, you may note significant numbers of Perseids before midnight, something of a rarity with meteor showers.

These meteors are fast (60 km/sec) and usually bright. You can expect to see something like 50 per hour.

Planet Finder August 1979

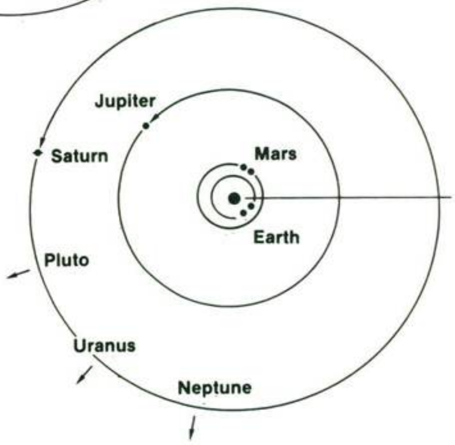

+40°
-40°
11
14
6h
18
6h
♂
1
♃
☿
♀
31
12h
12h
26
♇
1
⛢
♆
4
18h
18h
8
+20°
-20°

The Planets in Their Courses


Mars
Venus
Mercury
Earth

The positions of Mercury, Venus, Earth, and Mars in their orbits are shown for the beginning, middle, and end of the month. (Mars for the beginning and end only.) The vernal equinox is the line at right.

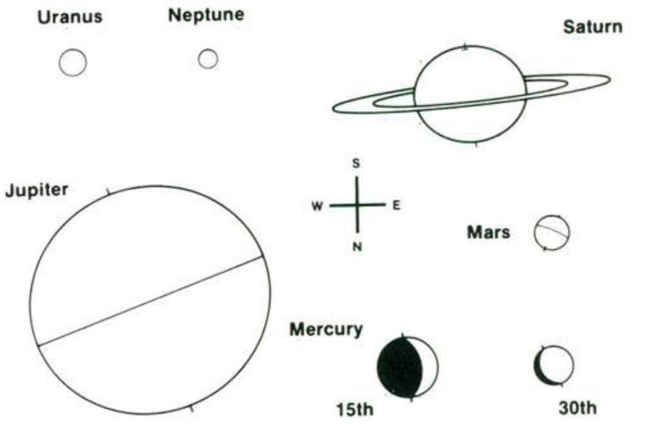
The orbits of Earth, Mars, Jupiter and Saturn are shown at right. Earth and Mars' positions are for the first and last of the month; Jupiter and Saturn for midmonth. The outermost planets' directions are indicated.


Jupiter
Saturn
Mars
Earth
Pluto
Uranus
Neptune

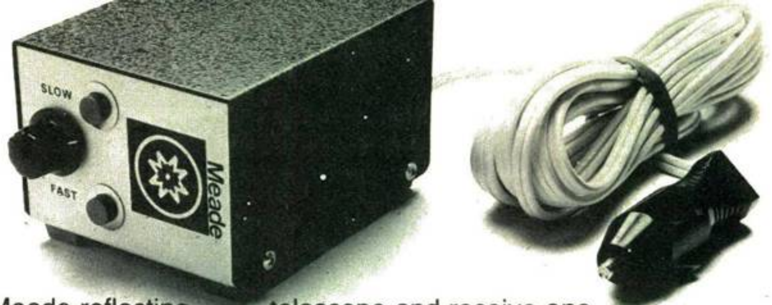
Positional Data

Planet	Date	R.A. (1979.7)	Dec.	Mag.	Distance (AU) from Earth	Distance (AU) from Sun
Mercury ☿	10	$8^h18.8^m$	16°04.9′	+1.6	0.70	0.38
	20	$8^h40.3^m$	17°39.2′	+0.1	0.93	0.33
	30	$9^h41.9^m$	15°11.4′	-1.0	1.18	0.31
Venus ♀	10	$9^h01.2^m$	18°05.2′	-3.5	1.72	0.72
	30	$10^h38.0^m$	10°08.5′	-3.5	1.73	0.72
Mars ♂	15	$6^h18.6^m$	23°44.3′	+1.5	1.99	1.51
Jupiter ♃	15	$9^h32.1^m$	15°21.6′	-1.3	6.35	5.34
Saturn ♄	15	$11^h03.7^m$	7°58.2′	+1.2	10.31	9.38
Uranus ⛢	15	$14^h58.8^m$	-16°38.3′	6.0	18.75	18.70
Neptune ♆	15	$17^h07.5^m$	-21°27.9′	7.7	29.82	30.28
Pluto ♇	15	$13^h27.3^m$	8°59.7′	14.0	30.76	30.22

Telescope View


Uranus
Neptune
Saturn
Jupiter
S
W
E
N
Mars
Mercury
15th
30th

Free! Meade Drive Corrector with every Telescope.*



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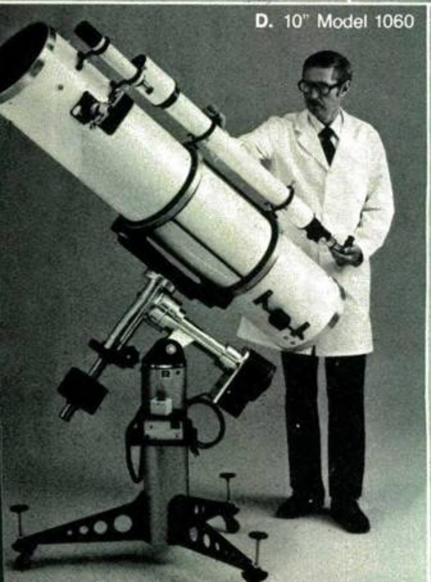
A. 6" Model 591

B. 6" Model 645

C. 8" Model 826


D. 10" Model 1060

E. 8" Model 880
F. 12½" Model 1266

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E. MODEL 880: 8" f/6 with Motor Drive	**995.00**
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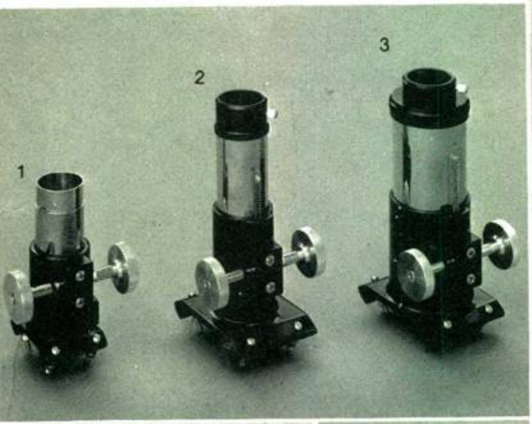

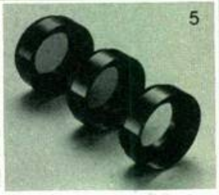

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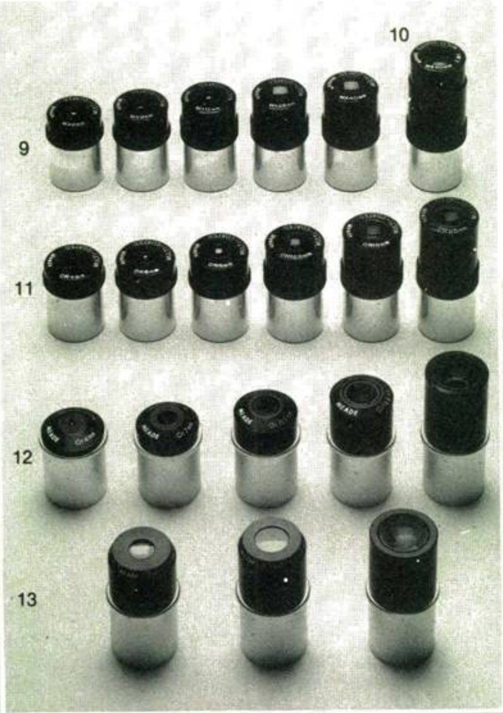

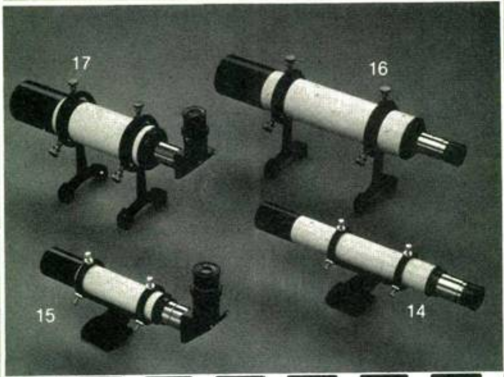

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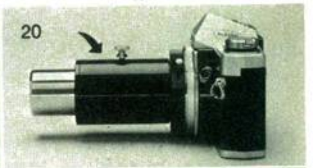

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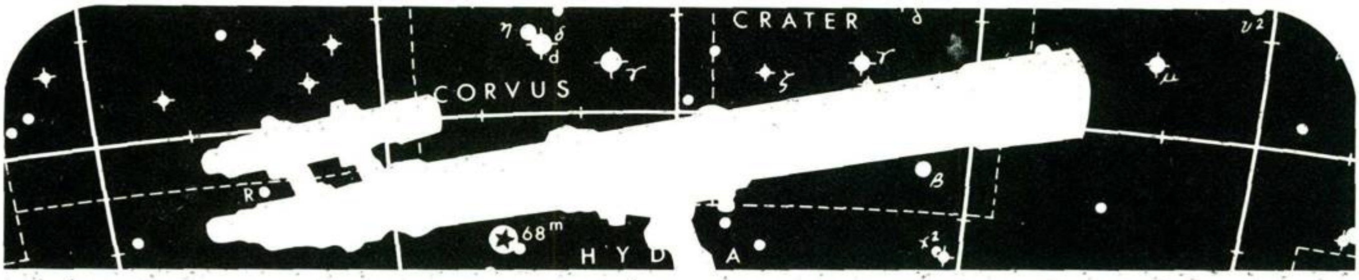


EQUIPMENT ATLAS

More about Nebular Filters

Nebular filters, an observing accessory that didn't even exist a year ago, now lie side by side with oculars, star diagonals, barlows, and other standard equipment in many observers' accessory cases. Used to view nebular objects with telescopes of moderate to large size, these filters markedly increase the usefulness of your instrument because they can darken the sky background, which may be contaminated with light pollution, without dimming the nebular object itself very much. Understanding the limits of what these filters can and cannot do, and acquiring a basic understanding of how they work, is important in making a wise choice of filter.

Some of the basic information you'll need is available in "Nebular Filters," ASTRONOMY, March 1979, page 51. Included in this article are data on two more filters and some background information requested by some of ASTRONOMY's readers.

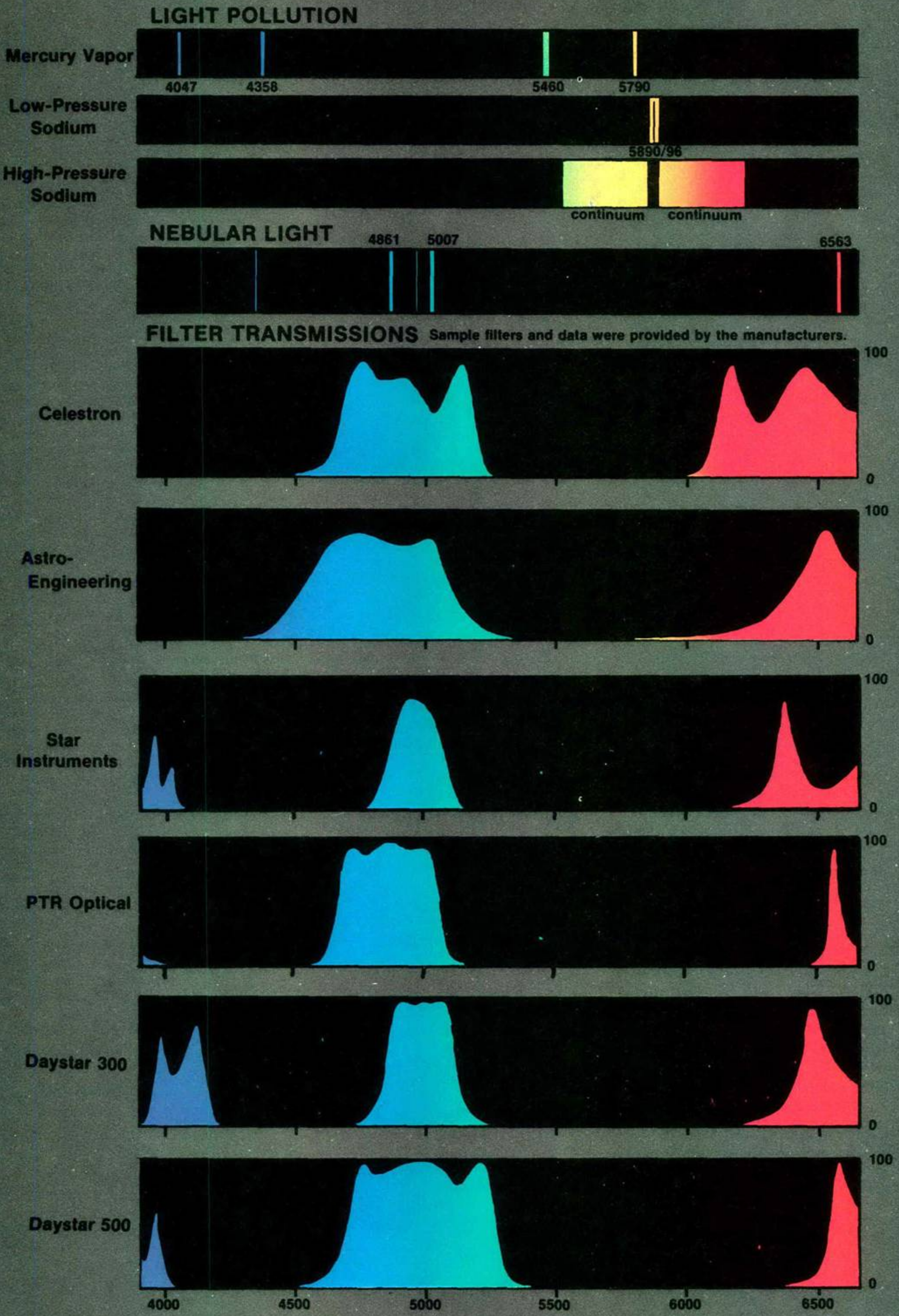
The first thing you should know about in considering a nebular filter — and the reason why nebular filters are possible at all — is the nature of starlight and nebular light. Light from many kinds of astronomical objects — stars, galaxies, planets — is continuously spread across the visible spectrum. (Properly speaking, there may be a few dark lines superimposed on the continuum, but they have very little effect on nebular filters. They are very important to astronomers though, because they contain a great deal of information about the physical conditions of a star.) The light from gaseous nebulae, however, comes from a small number of spectral lines, or narrow wavelength bands, principally due to gaseous hydrogen, helium, oxygen, sulfur, and so on.

A line spectrum instantly identifies the object that produced it as a cloud of glowing gas. Humanity uses electrically-excited clouds of glowing gas too, enclosed in glass or quartz globes, as street lamps. Much of that manmade light eventually finds its way into the sky to block out the stars and nebulae beyond. Luckily streetlighting uses metallic vapors, mainly mercury and sodium, whose wavelengths do not, for the most part, coincide with the wavelengths of light from nebulae.

A nebular filter is an interference filter, a type of filter made of multiple layers of evaporated dieletric materials, designed with two goals in mind: 1) to block as much light from artificial lights as possible, and 2) to transmit the maximum amount of light from nebulae. If the wavelengths of the lines from the terrestrial and celestial sources coincided, they would be impossible to separate; fortunately, they do not. The major nebular lines occur at 4861, 4958, 5007, and 6563 Angstroms, while the worst light pollution lines lie at 4047, 4358, 5460, 5790, 5890, 5896, and in some localities there is a broad band between 5600 to 6200 Angstroms. While they clearly aren't coincident, the lines are well enough mixed that filters before the current generation of interference-type nebular filters could not entirely separate them. Today you can buy a pretty good filter to do this job for a very reasonable price. When you slip one of these nebular filters over your eyepiece, the background fog drops greatly while the nebula continues to shine with only slightly diminished brightness.

Non-nebular objects seen with a nebular filter are not as dramatically improved as are nebular objects. The nebular filter blocks light from an object emitting a continuous spectrum as well as light from the sky, so both are made fainter. If the blocking more than makes up in contrast for what the filter removes in total light, then objects such as globular clusters and galaxies will be improved in telescopic appearance. Generally though, the improvement is marginal, and switching to a higher power eyepiece, which also darkens the background, is likely to give more psychologically-satisfying results.

Nebular filters now come in a variety of mounts to fit several standard eyepiece sizes and threads. If your eyepieces are not internally threaded, or you don't have one of the telescopes that use standard photo filter sizes, then it may be somewhat inconvenient to mount a nebular filter "before" the eyepiece in the light path. You can always hold the filter over the eyepiece, which permits a rapid comparison of an object with and without the filter, or you can purchase



Sample filters and data were provided by the manufacturers.

Nebular Filter Suppliers

Astro-Engineering
437 W. 19th St.
Costa Mesa, CA 92627

Cross Optics
P.O. Box 27292
Escondido, CA 92027

Celestron International
2835 Columbia St.
Torrance, CA 90503

Edmund Scientific Company
Edscorp Building
Barrington, NJ 08007

L. Henzl & Associates
P. O. Box 7000-38 A
Rolling Hills, CA 90274

Meade Instruments Corp.
721 W. 16th St.
Costa Mesa, CA 92627

PTR Optics
145 Newton St.
Waltham, MA 02154

Star Instruments
17972 Sky Park Circle, Suite K
Irvine, CA 92714

Star Quest Enterprises
378 South Tustin Ave.
Orange, CA 92666

Many telescope dealers may be carrying nebular filters by the time this article appears in print.

an adapter to hold the filter in front of an unthreaded eyepiece. Some form of holder is desirable for prolonged observation of deep-sky objects.

Nebular filters don't look like ordinary colored glass filters; they look like little mirrors when you see them at a distance. If you look at them up close, they generally have a bluish or green cast that is pronounced when you look through them. If you tilt the filter a bit while looking through it, you'll see it change color, most often to a pink or red. The transmission bands of interference filters are different for light entering at different angles, somewhat in the same way the colors of an oil slick change.

The mirror effect which you see is due to the fact that the filter doesn't absorb light pollution, but simply reflects it back. It can sometimes be troublesome when observing: if there are lights in your vicinity, you'll suddenly find yourself seeing light reflected off your eye, into the eyepiece, off the nebular filter, and back out and into your eye again. One way to cure this is to use a rubber eyecup on the eyepiece so your eye is in the dark (which helps your dark adaption at the same time); another is to toss a square yard of black cloth over your head and the eyepiece.

The manufacturers of nebular filters have invested a great deal of time and money in improving their products, and they are continuing to improve them all the time. It's therefore impossible for ASTRONOMY to provide an evaluation of different brands of nebular filters, as many readers asked us to do, without running the risk of being out-of-date the day we go to press. Even the transmission curves we have included in this article may not be accurate by the time you read this. We will say this much however: of the filters tested by ASTRONOMY, all produced improvement on nebular objects, although some filters were better than others.

What should you be looking for in a filter? It's difficult to answer. No one specification can predict how a filter will perform; no one transmission, blockage, ratio, passband, or wavelength tells the whole story. First, it depends on a blending of external factors, such as: 1) the magnification and aperture (hence the exit pupil) of the telescope, 2) the quality of the sky and mix of polluting light sources, and 3) the brightness and spectral composition of the nebulae you're going to observe with it. Second, it depends on the specifications of the filter itself: 1) the blockage of light pollution lines (i.e., how much "leaks" through the filter), 2) the filter transmission at each of the nebular lines (how much of the nebular light comes through to you), 3) the sensitivity of the filter to tilt (transmission is angle-dependent in these filters), and 4) the amount of continous spectrum light transmitted in different parts of the spectrum. Finally, there are observer-dependent factors to consider, such as: 1) the spectral sensitivity and degree of dark adaptation of your eyes when you observe, 2) your personal preference for magnification, and 3) your personal background, experience, and the expectations you bring to the eyepiece.

If this looks like a difficult technical problem to you, you're right. There are no hard and fast answers, especially when you consider that the filter is basically evaluated by a subjective criterion, i.e., "Does it make nebulae look better to you?"

The following rules-of-thumb appear to be true and represent an enormous shortcut in the time and effort involved in making a complete technical assessment of filter performance:

- Nebular filters work best at low powers, i.e., in the 4 to 8 power per inch of aperture range. This means the exit pupil of the telescope will be 3 to 6 millimeters. The large exit pupil means you see a high surface brightness. With small exit pupils, the background is already fairly dim, and the filter appears to be less effective.
- Nebular filters are most effective on larger telescopes because there are more celestial objects available to larger telescopes. An 8″ telescope, for example, reaches several hundred objects that a filter can augment. The bigger the telescope, the more objects there are to be improved.
- Unless you have a specialized deep-sky observing program, there are relatively few objects to see with a small telescope. In a 4″ RFT at low power, most objects are diminishingly small at 4x per inch. In a small refractor, the exit pupil is always too small unless the power used is extremely low.
- If you live in a heavily light-polluted area, place emphasis on obtaining good light pollution blockage. Be especially sure that the transmission around 6200 Angstroms is low if you live in an area with high pressure sodium lamps. Mercury lamps are much easier to block, but not all filters block it well.
- If you live under good country skies, place emphasis on getting high transmission of nebular light and relax the requirements on blocking. As long as there isn't much light pollution to block, you'll want high transmission for as much nebular and stellar light as possible. Low transmission reduces your telescope's effective aperture.
- When you get the filter, look at some streetlights with it. A good filter should make the pool of light under the lamp difficult to see. If you can see two distant faint streetlamps, one mercury vapor and the other tungsten, the filter will dim the mercury lamp much more than the tungsten lamp if it's good.
- There are no useless nebular filters on the market, although some are better than others. The performance of all filters depends on many factors; just because a filter doesn't perform well on one particular task, doesn't mean it's a poor filter.
- *Galaxy* is a trade name and not a filter for looking at galaxies. Nebular filters, in general, don't improve telescopic views of non-nebular objects very much.
- Insist on a money-back-return or replacement policy on nebular filter purchases. Although the manufacturers have good quality control, a few bad filters do slip through. If you get one of them, you shouldn't be stuck with it. It's up to you to be polite and understanding when returning a filter, and you must, as with any merchandise, return it in pristine condition.

— Richard Berry

Catch a Falling Star

by
Roy E. Gephart

Look up on any moonless night and before long you'll see several meteors streaking silently across the starry background. Now and then an exceptionally bright one appears in a burst of light to outshine all the stars and planets during its fiery plunge into the atmosphere.

Photographing these meteors requires no elaborate equipment. Meteor photography begins with a single camera, a tripod, and a roll of high-speed color or black and white film. What makes it fun is that your efforts will be rewarded with unique and dramatic pictures.

Meteor photography can be as easy as mounting your camera on a tripod, pointing it skyward, and beginning a time exposure. Yet while you're waiting for that first meteor, you may start to wonder about the answers to several questions: How bright a meteor can I photograph? How long might I wait to photograph it? Are some lens settings and films better than others?

Knowing Your Equipment

Not all meteors zipping through your camera's field of view will be recorded photographically. Some are simply too faint. But there are techniques to predetermine which meteors your equipment will record.

One method involves taking many time exposures of the night sky while keeping a written record of the estimated magnitude of each meteor passing through the camera's field of view. The processed film will show the faint meteors were too dim to be recorded, others left only a faint trace, but the bright ones were preserved as luminous trails. This is a time-consuming and tedious task, however. You can try a much simpler technique on the next clear night.

Load your camera with high-speed film (400 ASA, for example) and mount it on a sturdy tripod which allows smooth head motion. Let's assume you attach a normal 55 mm f/2 lens, open the lens to the f/2 stop, and focus to infinity. Photograph a star field, such as the constellation Orion, for 30 seconds, and then, with the lens remaining open, smoothly pan the camera at an angular speed of about 15° per second from its original position. Stop the exposure after panning 30° to 45°. The resultant picture will show star trails for all the stars bright enough for your equipment to record. Each star becomes a simulated meteor. Identifying the individual stars is easy because the original star field was photographed prior to camera motion. Then just look up the magnitudes of the recorded stars in an atlas or catalog to estimate the range of magnitudes over which your camera can record simulated meteors. You should repeat this procedure several times and compare the results.

Using the lens and film described above, your test will probably show no streaks recorded for stars or planets dimmer than +2 magnitude, faint streaks for those between magnitudes +2 and 0, then stronger and stronger steaks until you get prominent trails for everything brighter than -2.

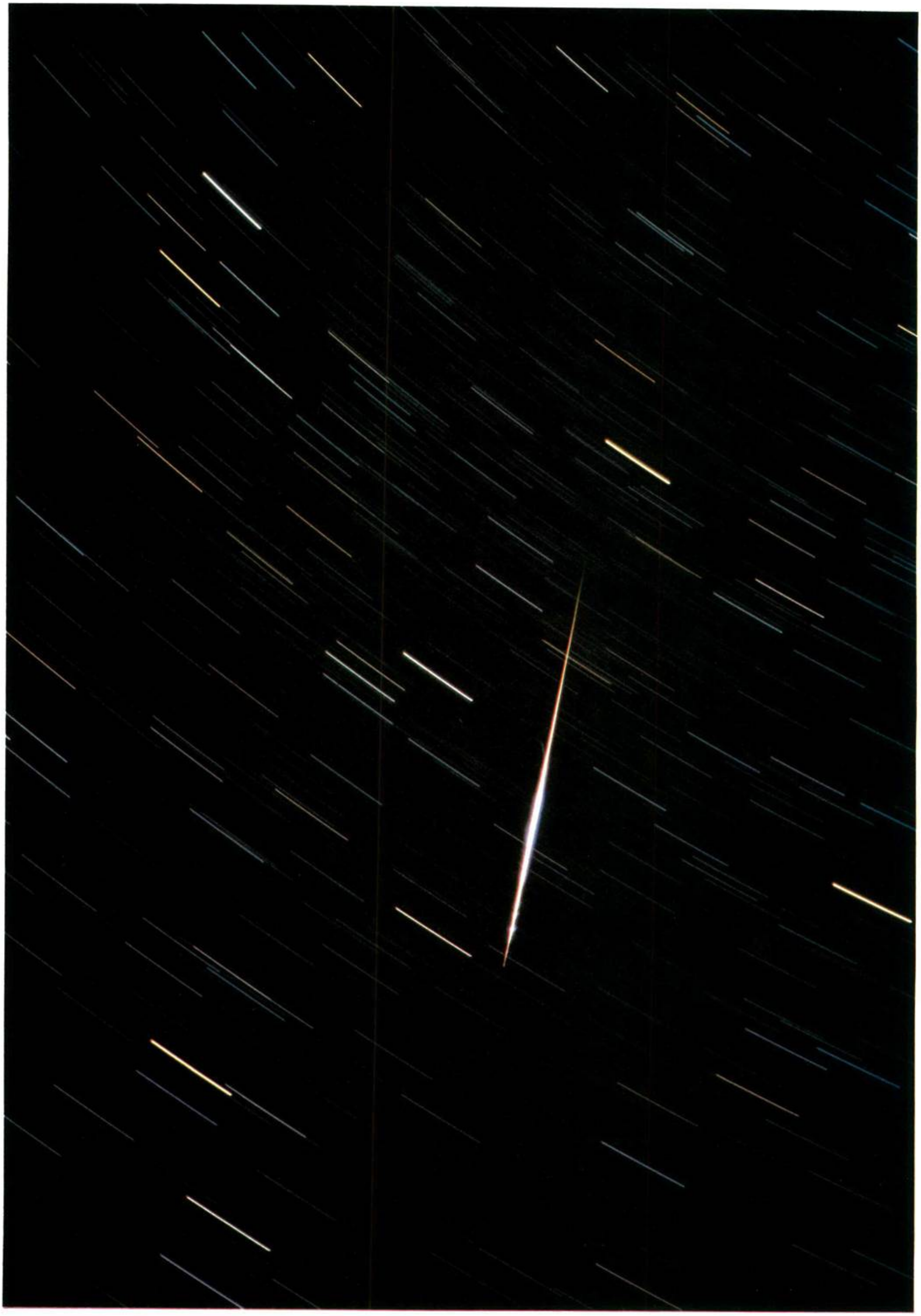
Having this information for 400 ASA film and remembering (1) a difference of one magnitude equals a 2.5 to 1 ratio in brightness and (2) 400 ASA film is twice as light sensitive or "fast" as 200 ASA (or four times that of 100 ASA), you can now construct a graph showing a meteor's recordable magnitude as it depends on film speed for your equipment. (See the left-hand diagram on page 51.)

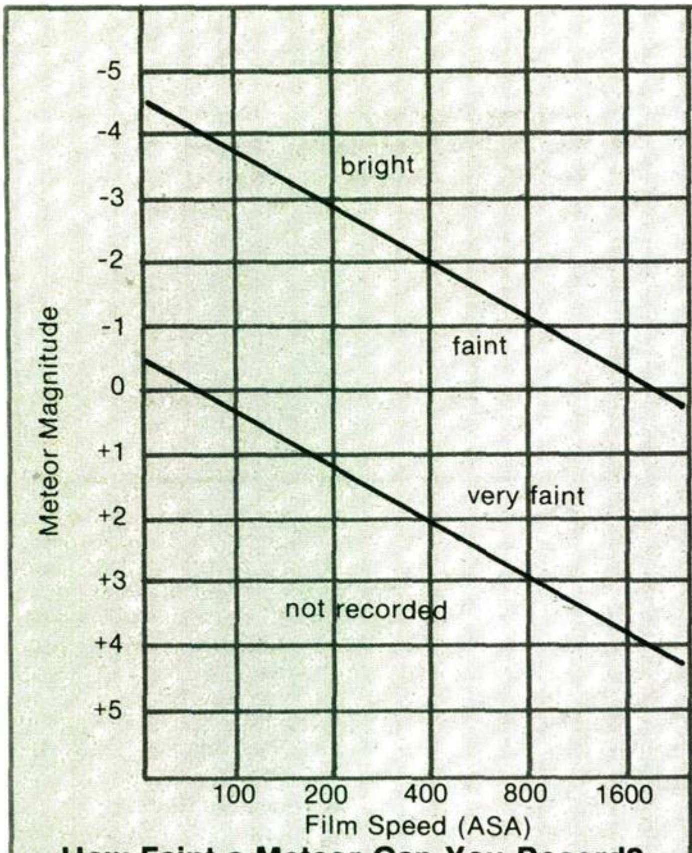
Meteors fainter than the top line on this graph cannot be photographed because they emit too little light. Those falling between the lines are only faintly visible on the processed film. Meteors brightening to magnitudes below the lower curve are best recorded.

Such a graph can answer many questions about what equipment and film to use in meteor photography. For example, which meteor magnitudes could 100 ASA film record with a 55 mm f/2 lens? The graph shows a meteor must attain +0.5 magnitude to be dimly recorded or -3.5 or brighter for a brilliant luminous trail. This is four times brighter than required for an equivalent image using 400 ASA film! Meteors brighter than +3.0 magnitude are recorded using 1200 ASA film. Higher speed films significantly widen the range of meteor magnitudes available for photography.

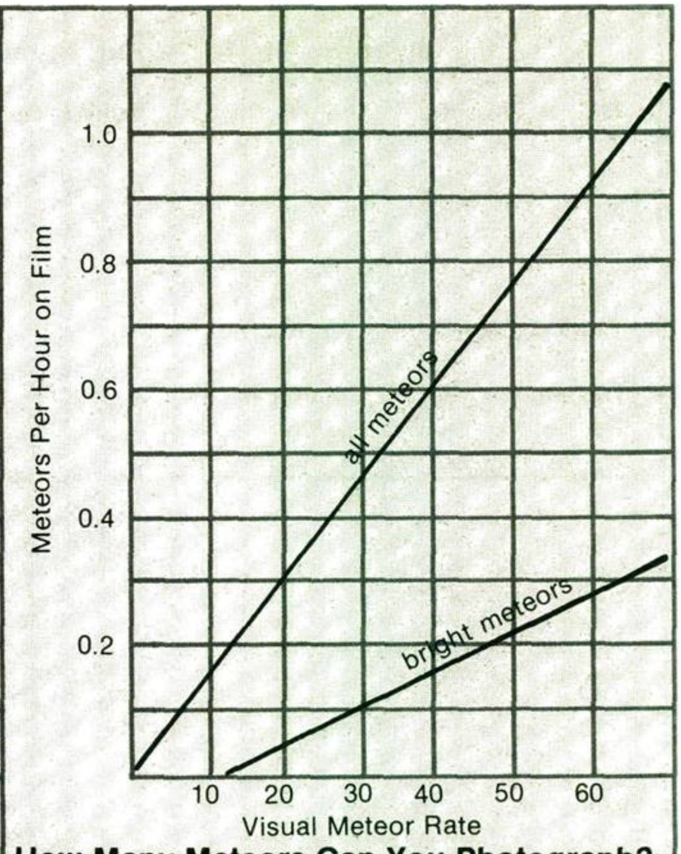
The lens setting is also important, for it determines the quantity of light reaching the film. Here, a simple rule applies — the wider the better! Large openings (smaller f numbers) pass more light. Thus an f/2 lens is "faster" than an f/4. Twice the light is transmitted per unit time when the lens is opened one full "stop," for example f/4 to f/2.8, and four times the light when opened two stops — in this case to f/2.

An f/2 lens will record meteors 0.8 magnitudes fainter than one of f/2.8, and 1.6 magnitudes fainter than an f/4 lens. Knowing the amount of light passing through different lens openings allows you to adjust the lines to fit a variety of lens settings. Some cameras have very fast f/1.4 lenses. These photograph fainter meteors. Raise the lines 0.8 magnitude to adjust





How Faint a Meteor Can You Record?



How Many Meteors Can You Photograph?

for this lens. You now have a method to determine quickly your equipment's effectiveness for meteor photography using a variety of lens settings and film speeds.

Meteor Photographic Rates

Your meteor photographic rate during any shower can be estimated by photographing for several hours and then plotting your rate of success versus meteor activity. Naturally, such an empirical relationship is only a statistical average. Any one picture may take a longer or shorter exposure time.

On any given night, five to ten "sporadic" meteors are visible each hour. However, this count may increase to 20, 40, or 60 meteors per hour during a meteor shower. Such times offer a fine opportunity to determine the average photographic rate for a wide range of meteor activities. For example, if you photograph 2 meteors during 10 hours of exposure during a shower displaying 50 meteors each hour, then your photographic rate is one meteor per 5 hours. Keeping such records over several nights enables you to construct a diagram showing meteor photographic rates versus meteor activity. (See the right-hand graph above.)

The hours invested seem amply repaid when you capture a bright meteor on film. This particular meteor was photographed at 2:40 a.m. on August 13, 1978 using a camera with a 55 mm f/2 lens on Ektachrome 200. The constellation Triangulum is in the background sky, trailed by the ten-minute exposure. This was a particularly brilliant meteor, estimated to be magnitude -5, or somewhat brighter than the planet Venus. Photograph by Roy E. Gephart.

This graph is based on photographic rates of the mid-August Perseid meteor shower for 1974, 1975, and 1977, using a total of about 85 hours of meteor photography. Standard single lens reflex cameras were used each mounted with a 55 mm f/1.8 or f/2 lens open to its widest f/stop. High Speed Ektachrome specially processed by Kodak Laboratories to an effective film speed of 400 ASA was used, but today's Ektachrome 400 should be better yet.

The average photographic rate for meteors of all recordable magnitudes is plotted along the top line. The lower line gives the photographic rates for meteors equal to or brighter than -2 magnitude. As in the first graph, meteors on or below this lower line are recorded as bright luminous streaks using ASA 400 film.

Assuming the photographic rate for Perseids over nights of differing activities corresponds to a "typical" meteor shower, you can then estimate the average time required to photograph a meteor for any shower. For example, suppose you plan to photograph a Geminid shower during the shower's peak activity of 50 meteors per hour. Draw a vertical line up from the mark indicating 50 meteors and let it intersect the two sloping lines. Your photographic rate for meteors of all recordable magnitudes (upper line) will be .75 meteors per hour or 0.2 meteors per hour for those meteors brighter than -2 magnitude (lower line). These rates correspond to photographing one meteor each 1 hour 20 minutes and each 5 hours respectively.

Thus, this graph lets you quickly assign an average photographic rate to any meteor shower or shower activity. A few examples are given in Table 1. If a shower peaks at some predictable rate over several days, then the photographic rate for each night can be estimated. Remember these rates are *averages* for a single camera, so sometimes you'll have good luck and sometimes bad.

If those hours to get one meteor sound long, remember you can decrease the number of hours required by increasing the number of cameras used. An average of 10 hours is needed to capture one bright Orionid but this can be reduced to only 3 hours 20 minutes by using three cameras. One proviso, though: each camera must be photographing a different section of the sky.

Each meteor shower is unique for its radiant location as well as meteor activity, color, velocity, and magnitude. Some showers such as the

Average Photographic Rates For Selected Meteor Showers

Meteor Shower	Peak Date	Peak Meteors per Hour (Visual)	Time to Record Meteor of Any Recordable Magnitude (Hours)	Time to Record Meteor Brighter Than -2 Magnitude (Hours)
Lyrids	April 21	15	5.0	50
Delta Aquarids	July 28	25	2.5	13
Perseids	August 12	60	1.1	3.3
Orionids	October 21	30	2.2	10
Geminids	December 14	50	1.3	5

Taurids and Geminids are rich in bright fireballs while others are not. All these factors determine the true photographic rate for any one shower. Yet our graph or your own will provide a reasonable estimate of the average time required.

Camera Lenses and Film

Nearly any camera is usable for meteor photography as long as it can be mounted on a sturdy support and its lens opened for time exposures. The important factor is transmitting the maximum amount of light through the lens and onto the film during that moment a meteor is visible. For this reason, fast lenses between f/1.4 and f/2.8 are best suited for meteor photography. Lenses slower than f/2.8 will also work — but expect to record fewer meteors. Since most modern lenses are of high optical quality, open them to their widest aperture for all time exposures.

A good standard lens is one of normal focal length, or 50 to 55 mm with most single lens reflex cameras. These lenses cover a 43° to 46° angle of view. The meteors photographed will closely resemble their visual appearance. Wide-angle lenses (35, 28 or 20 mm) span a larger portion of sky, but a given meteor will cover a shorter photographed length. A meteor trail crossing ¼ of the frame with a 55 mm lens will cover only ⅛ of the frame if taken with a 28 mm lens. Lens selection is a personal decision only you can make. If a shorter focal length lens is selected, a moderate wide-angle, such as 35 mm, makes a good choice. It covers a 62° angle of view. Shorter focal length lenses do cover a larger area of sky but they compress most meteors into very short streaks. Telephoto lenses should not be used because they have very narrow fields of view.

Concentrate only on high speed *films:* Ektachrome 400 is an excellent color film. If you prefer black and white, Tri-X (400 ASA), Ilford's HP-5 (400 ASA), and 2475 Recording Film (1200 ASA) are suitable. You can expect more rapid sky fogging using 2475, however.

Exposure Time

The maximum time exposure with your equipment and film should be determined for each observing location, for sky light and haze varies from site to site. Under very dark skies, you can easily expose for 30 minutes. Closer to city lights, you'll need shorter exposures, as you will during dawn and with moonlight. Remember too that the greater the exposure, the longer the trails of the background stars. By keeping exposures down to 15 to 20 minutes, you'll reduce this star clutter. Guiding your camera on an equatorial mount eliminates star trails.

If you happen to see a meteor of recordable magnitude pass across the camera's field of view, stop the exposure right away so there will be fewer stars. If the meteor happens to leave a luminous vapor trail, try to record its dissipation in the upper atmosphere with a series of short time exposures lasting 5 to 30 seconds each.

Pointing the Camera

Your best chance of photographing a shower-related meteor is to point the camera 40° to 60° from the shower's radiant. Although the exact location is a decision only you can make, any aiming point has its own special advantages and disadvantages. Close to the radiant the meteor trails are shorter but brighter, while those farther away are longer and fainter. Consider too that meteors seen overhead are closer but fewer in number compared to lower altitudes where the lens scans a greater volume of atmosphere. Then why not just photograph near the horizon? The problem there is the thick blanket of air absorbs some of the meteor's light, making it fainter than those meteors directly overhead.

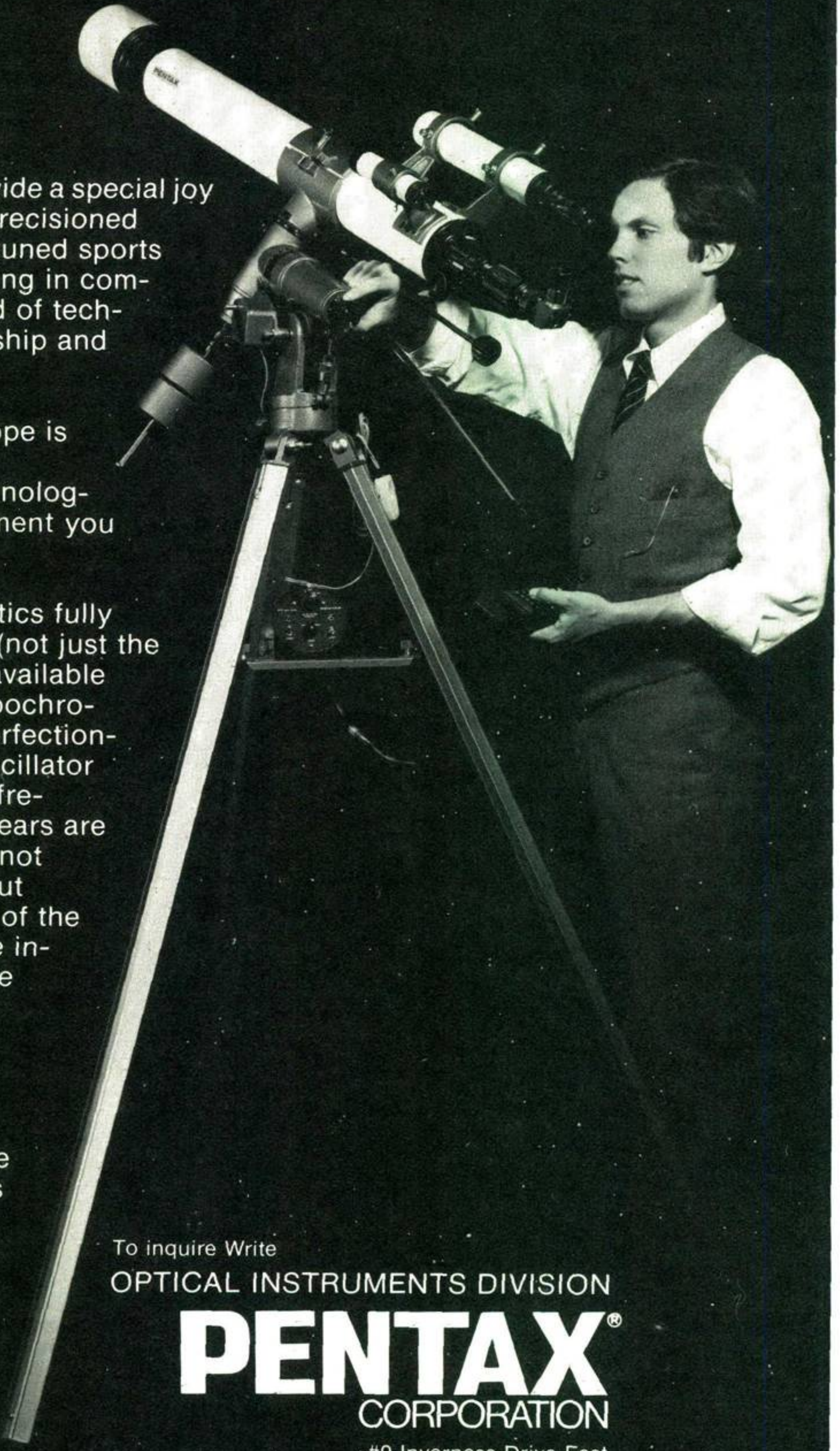
Camera orientation is also important. Many cameras have a rectangular view with one side 50% longer than the other. When you're photographing an area giving long meteor trails, such as directly overhead, slant the long axis parallel to the expected meteor path rather than perpendicular to it. This increases your chances of photographicing the entire meteor. Orientation is less important closer to the radiant where shorter trails are seen.

A Few More Hints...

Comfort is crucial. Don't expect to have a pleasant evening while only standing or sitting because your back and neck will quickly tire. You'll become tired and cranky and decide meteors are for the birds! A folding lounge chair is an indispensable addition to your equipment. In addition, overdress for the occasion. Night temperatures coupled with very little physical activity can make you cold and uncomfortable even when the temperature reading doesn't seem too bad. It's better to take along your long woolies even for an August shower such as the Perseids than shiver half the night. Too many clothes is better than too few.

One simple method of improving your photographic knowledge and of obtaining valuable reference data is to keep a notebook of your observations. A few words recorded for each photograph can transform a merely interesting picture into a well-documented photograph, worthy of personal pride and having potential scientific value.

Plan your meteor photography in advance. Check into when the meteor showers occur, and watch Sky Almanac for specific times and average meteor rates. Give serious thought to locating a suitable observing area and take care in choosing your equipment. Invite along other observers and interested friends — encourage them to bring additional cameras. Together you'll make a formidable team of meteor photographers, and the company helps pass the hours.



Some things in life provide a special joy and pride, like a well-precisioned chronometer or finely tuned sports car. Both have something in common—the special blend of technology, fine craftsmanship and functional design.

The Pentax 100 telescope is of this rare breed. It is possibly the most technologically advanced instrument you will ever experience.

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Many other features of this telescope make it the one and only choice for you. Put your hands on the controls of a Pentax 100. Then, and only then, can you appreciate the best.

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JUPITER

Pictorial

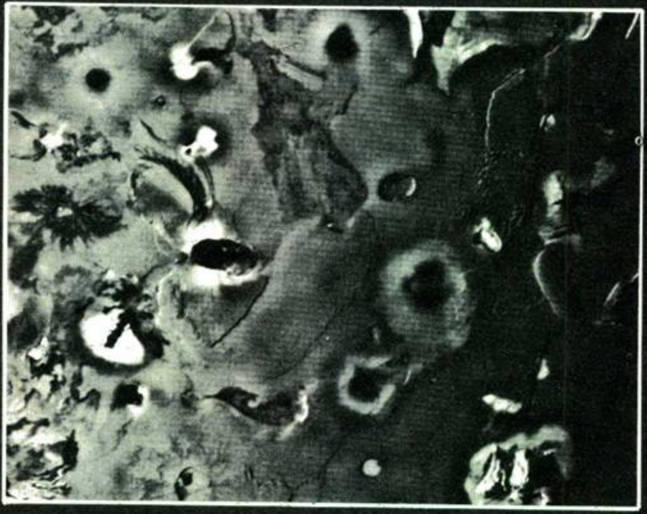
Once Jupiter was known only as the solar system's largest planet, veiled and banded with colored clouds, marked by a huge, strange Red Spot, and circled by four large moons and a number of tiny ones. Now it's as if we had never known this planet before, so many stunning discoveries have been made by the Voyager space missions. At the time these words are being written, Voyager 2, traveling four months behind its sister ship Voyager 1, has yet to make its sweep through the exotic jovian system, but more new findings have emerged from the on-going analysis of data already obtained.

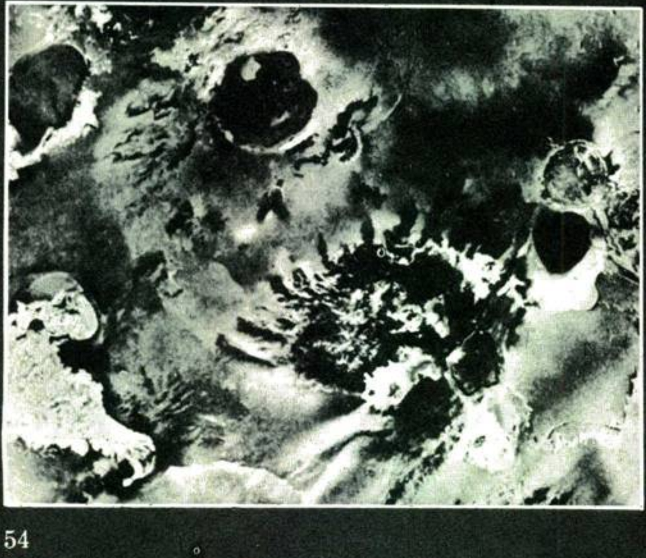
Commenting on the amazing and alien jovian system, the Voyager imaging team stated in the June 1 issue of **Science** that "the sense of novelty would probably not have been greater had we explored a different solar system. It seems clear that analyses of Voyager 1 data and of data to be acquired by the Voyager 2 and Galileo spacecraft will provide major insights into the origin and evolution of the solar system and, through comparative planetology, of our own planet."

Io, already famed as the oddest body in the jovian family and possibly in the whole solar system, has continued to produce surprises. Project scientists have now detected 30 to 40 wisps of glowing blue on photographs taken during Voyager 1's flyby. The wispy clouds are thought to be a kind of "blue snow," formed when gases vented along surface faults and cracks condensed and crystalized in the cold environment, scattering light at blue wavelengths. According to Dr. Laurence Soderblom of the U.S. Geological Survey, the vented gases are likely to be sulfur dioxide, also identified as the primary constituent of the gases erupted by Io's huge, highly-active volcanos.

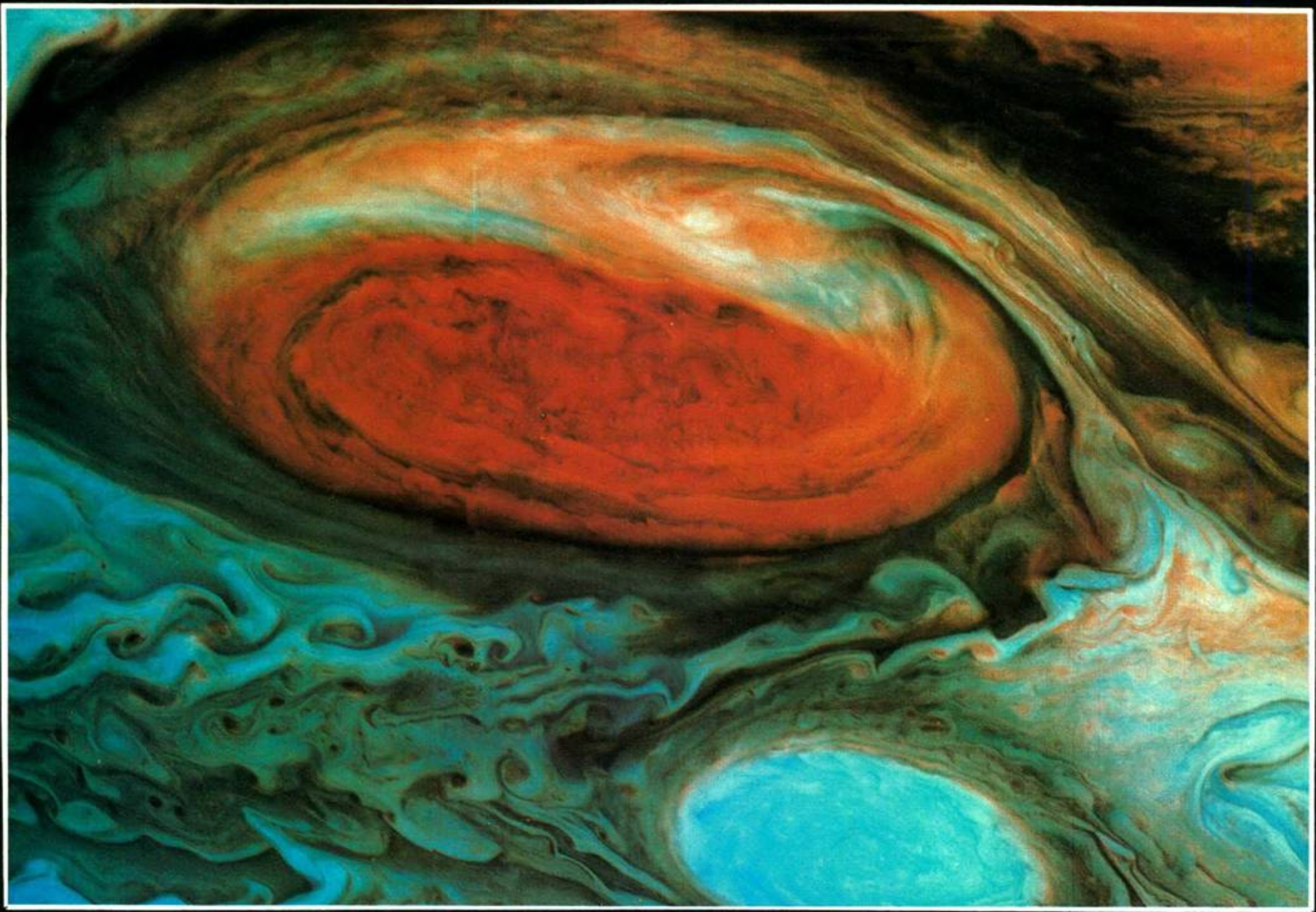
Io must have a tremendous amount of internal heat to fuel its nearly continuous volcanic activity, and the cause of this internal churning is still a puzzle. It is likely that jovian gravitational tidal forces provide the energy, as was suggested in a paper published just before Voyager 1's discovery of vulcanism on Io, but this mechanism implies that Io's polar regions should be hotter and more active. In fact, most of the volcanic eruptions so far observed have occurred within 30° of Io's equator. According to Dr. Norman R. Ness of the Goddard Space Center, the electromagnetic interaction between Io and Jupiter "may be an important source of heating," and this could help power Io's inner turmoil.

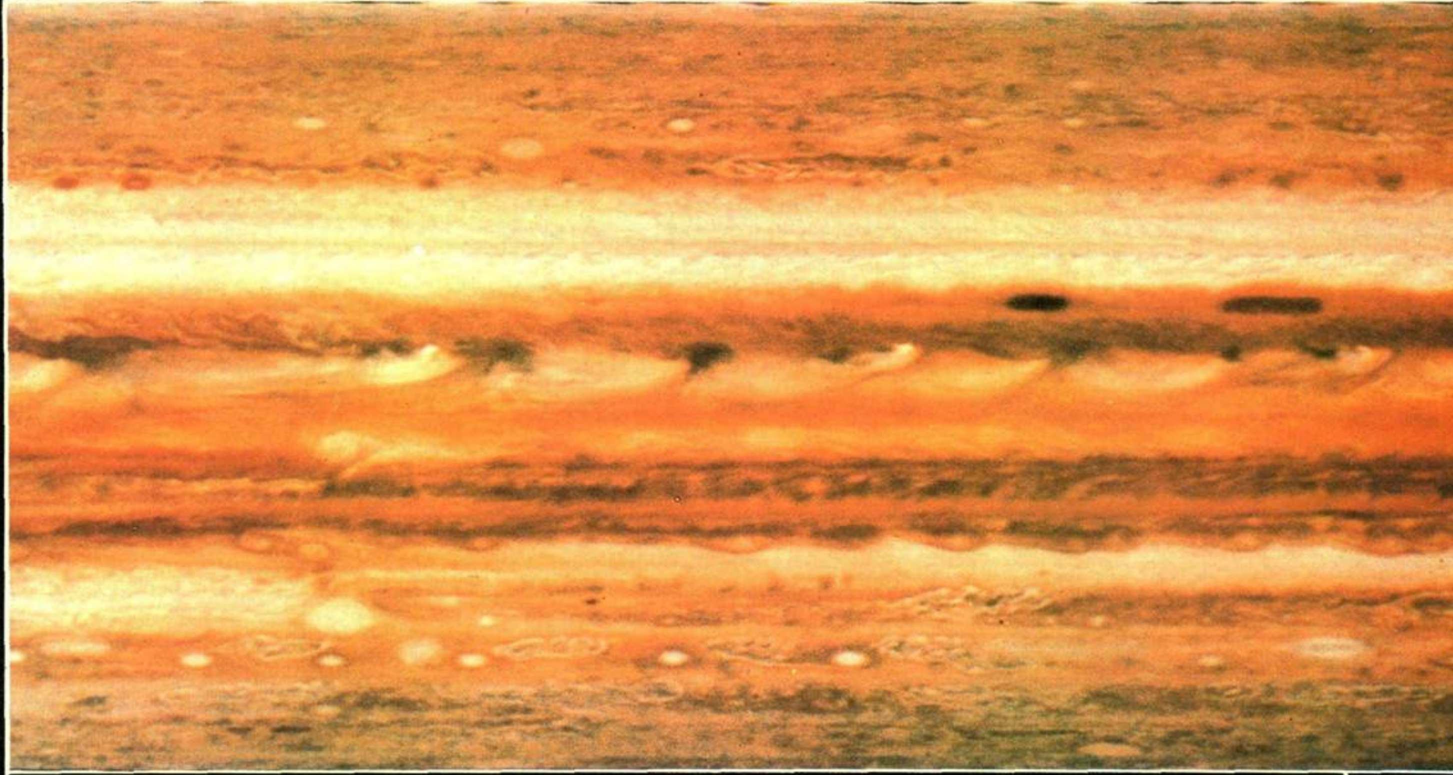
Actually the volcanos have been found to be cooler than expected. While most of Io's surface is at

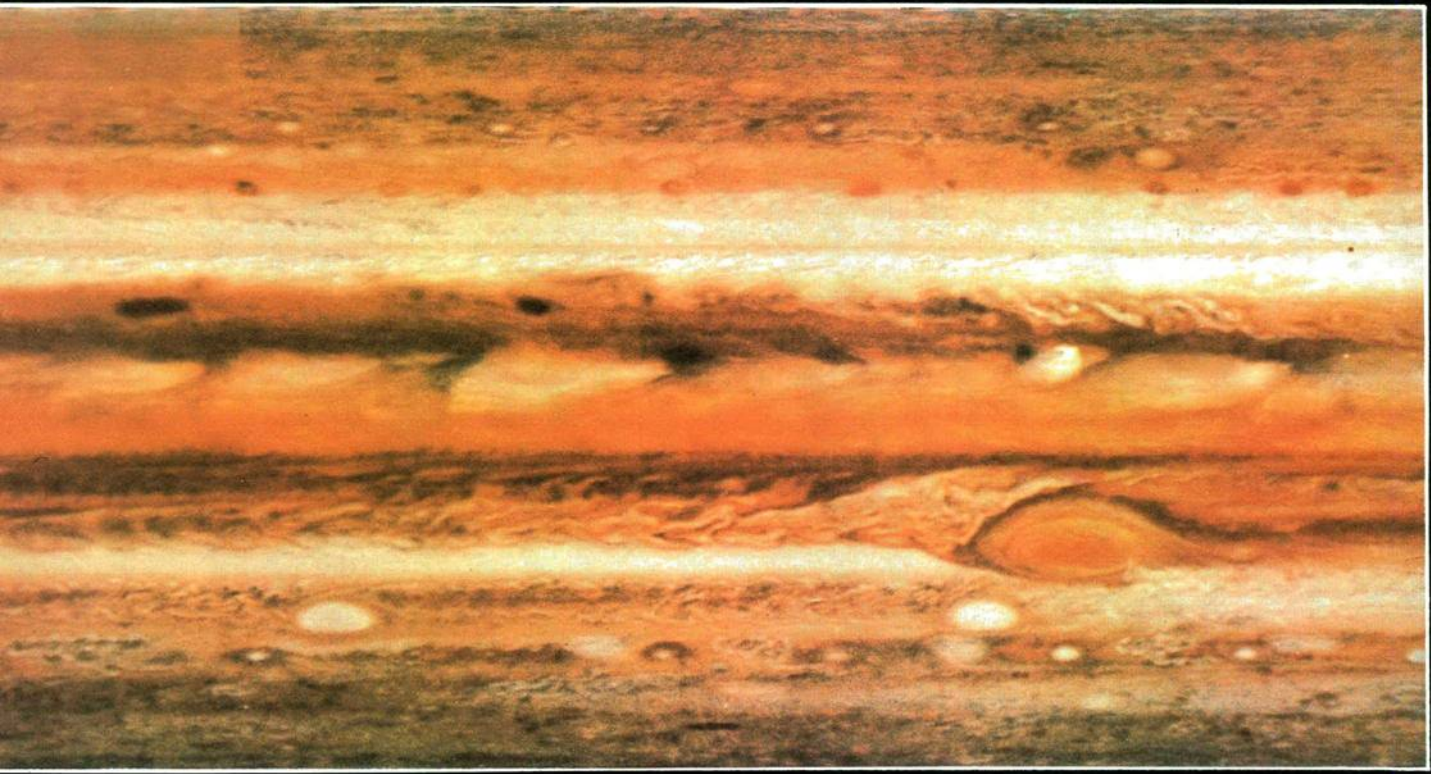




Left top: This wide-angle image of the surface of Io, about 1000 miles square, shows a variety of volcanic calderas, vast smooth plains, complex scarps, and rugged isolated mountains. Left bottom: Complex patterns highlight the flows, calderas, and other volcanic features visible in this high resolution image of Io's strange surface. The area shown is about 140 miles across. Facing page, top: This image of the Great Red Spot, seen in dramatic but unnatural, highly-enhanced color, reveals a great deal of detail. Note the puffy features inside the Spot, and the "reverse-S" spirals inside both the Spot and the white oval. The large white feature extending over the northern part of the Red Spot was observed to revolve counter-clockwise inside it with a period of six days. Facing page, bottom: This photograph of Io shows (upper center) what appears to be a volcanic caldera venting gases as a bright blue patch. The gas clouds may condense to form extremely fine, snow-like particles that appear blue. Several other calderas in this image have dark floors, which scientists believe may be pools of molten sulphur. JPL/NASA photographs.







Above: Ten three-color images obtained during a single jovian rotation were used to form this computer map of Jupiter's vast cloud system. The various bands and zones are clearly delineated, but far more detail is visible than can ever be seen from Earth. Left: These four color photographs show Jupiter's Galilean satellites in their correct relative sizes. Io (upper left) is slightly larger than Earth's Moon and Ganymede (lower left) is larger than Mercury. The relative color and albedo (reflectivity) have been preserved, although the full range of albedo differences between Europa (upper right) and Callisto (lower right) — more than a factor of three — cannot be easily displayed. JPL/NASA photographs.

temperatures below -235° Fahrenheit, the volcanic plumes were expected to be as hot as 230° Fahrenheit. Instead, one plume has been measured at only about 80° F, the temperature of a warm day on Earth.

Calculations indicate that one impact crater at least a kilometer in diameter should have been formed on Io every 50,000 years. So far, *not one* has been seen. But 15 constantly active volcanic vents on Io's surface could obliterate any such craters within 50,000 years. More than 100 large depressions similar to volcanic calderas on Earth and Mars have been identified, and a total of eight eruptions were actually observed, so there appears to be no problem in accounting for Io's lack of impact craters.

The second Galilean satellite Europa, which was not seen at high resolution by Voyager 1, is now estimated to be 20% composed of water. This leads scientists to speculate that Europa may be covered by a water and water-ice sheet as much as 60 miles thick. Like Io, Europa may also be internally active, for the same tidal forces which may heat Io also operate on Europa, although to a lesser extent.

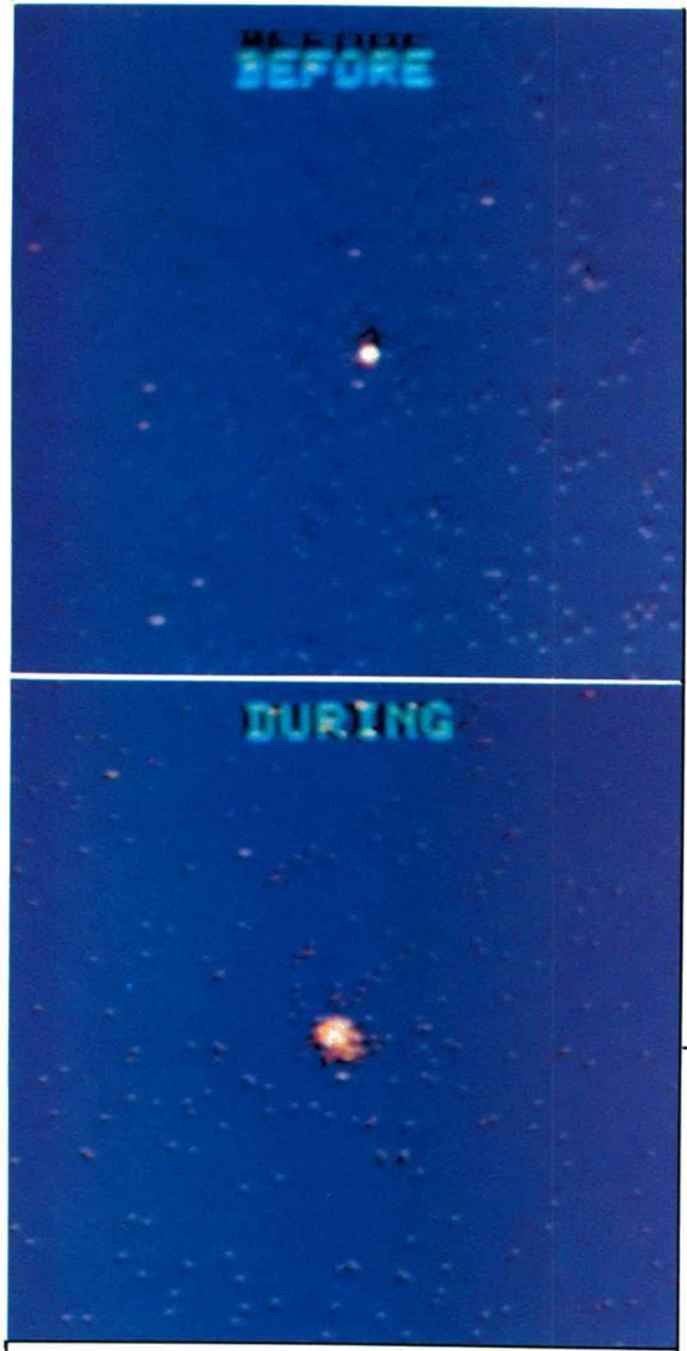
Ganymede, Jupiter's largest satellite, has been studied in detail. It may be composed of as much as 50% water by weight, and there is very little surface relief, suggesting that the surface may be viscous and subject to slow flowing and settling. It now seems certain that some complex form of tectonic movement of surface plates has happened on Ganymede, producing two types of terrain: older, highly cratered regions and younger, grooved and fractured stripes separating the more ancient sections.

Callisto has the lowest density of all, but not so different from that of Ganymede as had been thought. The two large ringed structures seem to have been formed relatively late in the period of heavy cratering (around four billion years ago), for fewer craters are found within these structures.

In following up on Voyager 1's findings, Voyager 2 has been reprogramed to examine certain features in more detail. In particular, a full ten hour photographic sequence of Io's volcanic activity is planned, with a single known volcanic area in view that whole time. Additionally, many images of Jupiter's dark side will be taken, in hopes of learning more about the extensive jovian lightning found by Voyager 1 as well as the aurorae in Jupiter's upper atmosphere. The ring system of Jupiter will be mapped in detail, including images from outside the ring plane, in order to determine its extent and structure. And as for Jupiter's clouds, early pictures returned by Voyager 2 at the time of writing have already shown significant changes from those taken by Voyager 1. A full report on Voyager 2's flyby with the first images and preliminary results will appear in the September ASTRONOMY.

AstroNews

Einstein Satellite Pictures X-Ray Burster



A strange celestial object known as an X-ray burster is pictured above before and during an outburst in March. The images were taken by the X-ray telescope aboard the Einstein Observatory satellite (HEAO-2) with very high time resolution and only a few minutes apart, but are shown here in 2.5 minute exposures. The X-ray image is the bright spot at center, which the telescope focussed to within a few seconds of arc. The image clearly became much brighter during the outburst, which lasted only 50 seconds. The burster is located within two arc-seconds of the center of the globular cluster Terzan 2. NASA photograph.

X-ray bursters, one of the most bizarre celestial phenomena ever observed, are relatively rare. Compact objects with an apparent diameter of less than 50 kilometers (30 miles), bursters are characterized by sudden, very intense increases in X-ray brightness.

A typical X-ray burst releases more X-ray energy in 10 seconds than our Sun does in an entire week. And despite a great deal of observational and theoretical study in the three years since X-ray bursters were discovered, their nature is still not understood. The bursts may arise from explosions similar to a helium bomb on the surface of a neutron star, or from violent instabilities in the flow of gas down a black hole.

X-ray bursters were first discovered by instruments aboard a satellite in 1976. Now, for the first time, the X-ray telescope aboard NASA's High Energy Astronomy Observatory-2 (HEAO-2) has photographed an X-ray burster. The picture was obtained in March by Jonathan Grindlay and other astronomers at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. The object was observed for 20 minutes, although the burst itself lasted only about 50 seconds. It is located within 2 arc seconds of the center of a globular cluster called Terzan 2 (17^h 24.3^m, $-30°46'$; 1950 coordinates).

Thus, in one 20-minute observation with the X-ray observatory, named "Einstein" by scientists, the existence of a steady and bursting X-ray source in the globular cluster was established, confirming an identification suggested earlier by Grindlay. This brings the known number of globular clusters containing X-ray sources to eight, of which at least six are also bursters; more than 130 globular clusters are known in our galaxy.

According to Grindlay, recent discoveries made it clearer than ever that something remarkable is occurring in the cores of globular clusters. It may be that they have collapsed to form massive black holes, or that compact binary systems containing either neutron stars or black holes are being formed to produce bursting X-ray sources. The black hole hypothesis predicts that the X-ray sources should be located very near the centers of the globular clusters since, as the heaviest object, the black hole would sink to the cluster's center.

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Jupiter's Hot Spot

Recent analysis of data obtained by Voyager 1 during its trek through jovian space has revealed what may be the hottest zone in the solar system yet measured. As the spacecraft crossed into the unique magnetic environment of Jupiter, its instruments detected a plasma composed of ionized hydrogen, sulphur, and oxygen now estimated to be at a temperature of between 300 and 400 million degrees. Even the interior of the Sun is estimated to be only about 20 million degrees.

The extremely high temperature of the plasma was no threat to the spacecraft because the plasma's density is very low, much lower than the plasma surrounding the Sun and is a greater vacuum than can be produced in a laboratory on Earth. The source of the plasma is tentatively believed to be Io because of the presence of sulfur and oxygen, elements uncharacteristic of the interplanetary medium or the solar wind. Io itself revolves about Jupiter within a plasma torus probably fed by that exotic world's extensive volcanic activity, and this plasma is thought to leak out into interplanetary space.

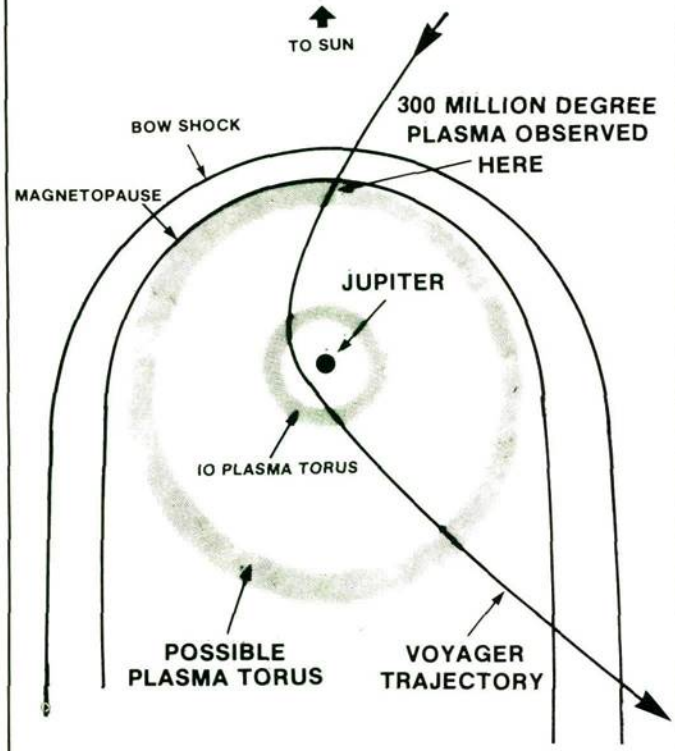
Voyager's ultraviolet instruments had detected an anomalous UV emission in the outer magnetosphere which project scientists were at a loss to explain, but it now appears this emission may be due to recombination of doubly-ionized sulfur and oxygen atoms in the plasma.

The sulfur and oxygen atoms are not completely ionized, as might be expected at such temperatures. According to Dr. S.M. Krimigis of Johns Hopkins University, one of the Voyager project scientists, "I would expect that [sulfur and oxygen atoms] are not completely ionized because the density is so low."

Dr. Krimigis said that the plasma, originating from Io, was probably transported to the outer magnetosphere and energized there by interaction between the planet's rapidly rotating magnetic field and the solar wind. He also noted that "the plasma appears to be co-rotating with the jovian magnetic field."

If this is so, it may mean that Jupiter is surrounded by a second plasma torus (in addition to that of Io), of lower density but at a much higher temperature. Ions in the torus would revolve around Jupiter once about every ten hours, with a speed of about 800 kilometers per second. Voyager 1, of course, observed the plasma only at one spot, as it crossed Jupiter's magnetopause on its way into the jovian system. Its trajectory out took it above the plane where the plasma might have been detected within Jupiter's magnetic tail.

"Whether the plasma forms a ring or an ellipse we cannot tell at this time," said Dr. Krimigis. "We will have to wait for the Galileo mission [a permanent Jupiter-orbiting station] to know for sure."



A 400" Telescope?

Earlier this year, astronomers from the University of California announced plans to design and build a 10-meter (400-inch) optical telescope. If constructed, the device would dwarf the largest optical telescopes now in existence, the 5-meter (200-inch) reflector at Mt. Palomar and a 6-meter (240-inch) instrument in the Soviet Union. It would have four times the light-gathering power of the Mt. Palomar telescope.

The announcement came from Dr. Donald E. Osterbrock, director of U.C.'s Lick Observatory, who along with a committee of astronomers from other U.C. campuses, is conducting an initial design study. The new telescope could quite likely provide new information on the origin of the universe, since it could detect light which left distant galaxies almost 10 billion years ago.

The growth of the astronomy department at the University of California and increasing light pollution affecting Lick Observatory have led to proposals in recent years for a new observatory location in California. In the summer of 1977, Joseph Wampler, an astronomer from the Santa Cruz campus, and Jerry Nelson, a physicist from the Lawrence Berkeley Laboratory, realized the desirability and feasibility of building a telescope larger than any in existence. Their proposal was accepted by U.C. President David Saxon, who authorized $270,000 for the design study and $75,000 for engineering studies at the Lawrence Berkeley Labs.

Only a few years ago, many scientists felt that the limits of optical telescope construction had been reached. Isaac Asimov wrote in his book, **Eyes on the Universe**: "On Earth, optical astronomy has reached its limit. The Hale telescope and the 600-centimeter telescope being built in the Soviet Union are astronomical dinosaurs, and it's unlikely that anyone will attempt larger mirrors still. The rapidly increasing engineering difficulties and expense put it out of the question." But recent advances in engineering, optics, and most importantly computer technology, have made it possible to design and build a 10-meter or larger reflecting telescope.

Dr. Osterbrock pointed out that the 5-meter Mt. Palomar telescope was designed in the 1930s; all large telescopes since then have drawn upon its basic design. "The problem with a large telescope is to make a structure that will keep the shape of a parabola and [hold] the detector at the point of focus no matter what direction the telescope is pointing," said Osterbrock. "All that requires engineering which can now be done with computers. Also, using a computer to control the telescope was not possible until recently."

Two design concepts are being studied for the telescope's mirror. The monolithic design would use a single thin piece of glass 10 meters in diameter which would be stressed into the proper shape. This design would use ultra-low expansion or fused silica glass to minimize temperature effects on the mirror's shape. The second design, called segmented or mosaic, would consist of 54 hexagon-shaped mirrors fitted together for an effective size of 10 meters. Each mirror could be individually tipped, and the entire mosaic would be kept constantly in the correct optical shape by microcomputers.

Whichever design is used, the final mirror will be 10 times lighter than a 10-meter mirror built in the conventional method of past years. "By making the mirror lighter, that makes everything else lighter," said Osterbrock, "and that reduces the cost."

In another attempt to reduce the telescope's size and cost, the U.C. astronomers are designing a much shorter focal length than has been used on previous large telescopes. While the focal ratio for the Palomar 5-meter was f/3, Osterbrock believes that a ratio of f/1.5 or f/2 is possible today. Optical expert Harland Epps of U.C.L.A. is designing the optical system that will make the shorter focal ratio possible. Without the shorter focal length, the proposed telescope would not only be twice as large, but twice as long, increasing the cost tremendously.

The total cost of the telescope will not be accurately known until the design study is completed in the summer of 1980. Rough estimates, however, put the cost at approximately $40 million. Since the prospects of obtaining large sums of money from the state government appear slim, the university hopes to get a wealthy individual or foundation to make a large donation. "We're looking for the James Lick of the 1980s," says Osterbrock, referring to the wealthy founder of the observatory that bears his name, who donated $700,000 in 1875. One purpose of the design study is to prove the feasibility of the new telescope and thus attract money for its construction. "I'm sure we can design the telescope, but I'm by no means sure we can get the money," Osterbrock conceded. "That's the most iffy part of it."

Several members of the committee are focusing their efforts on selecting a site for the proposed telescope. Although no possibilities were mentioned, the instrument will definitely *not* be located on Mount Hamilton, site of the present Lick Observatory, because of increasing light pollution from nearby cities. "We're building the largest telescope in the world...we'd really like to have the best site in the world," says Dr. Osterbrock. The actual site must meet five criteria: (1) clear weather, (2) excellent "seeing," (3) high altitude, to reduce the absorption of infrared, (4) accessibility, both for construction and use of the telescope, and (5) a site remote from present and future sources of light pollution.

The committee is studying sites in the western United States as well as other parts of the world. Inland, coastal, and island sites are all being considered. One location that is being frequently mentioned is Junipero Serra Peak, in the coastal mountains of Central California, considered by some to be the best location for an observatory in the continental United States.

Probably the most exciting aspect of the proposed telescope is the new possibilities in astronomical research that it will create. The main focus of the telescope will be "deep sky" research — the study of bodies outside of our own Galaxy. The giant reflector will be used "to look for very faint light sources — the most distant objects we can find," says Osterbrock. This area of research is likely to gain new information about the formation of the universe, since faint light sources as much as 10 billion years old could be observed. Current theories place the origin of the universe some 15-20 billion years ago.

The telescope should also greatly add to the understanding of stellar evolution, because both the birth and death of stars are very faint occurrences. The instrument could also be used in conjunction with the Space Telescope, an 86-inch instrument to be orbited in 1984, to make studies in the ultraviolet and infrared ranges of the spectrum. In our own solar system, the telescope could be used to study Pluto, Earth's most distant neighbor some 2 to 4 billion miles away. Comets entering our solar system from deep space are another possible target of the telescope.

The University of California astronomers hope that the public and state legislators will realize the value of the new knowledge the telescope could bring. Sandra Faber, an astronomer from the U.C. Santa Cruz campus and a specialist in the study of very faint objects, pointed out that work with the telescope would provide clues about the very origin of mankind. "Astronomers catch a lot of criticism because they don't put food on the table," she said, "but the public is extraordinarily interested in astronomy. We are answering questions that are part of the human spirit — who are we and where do we come from?"

Amateur Discovers Supernova

A supernova occurs when a very massive star explodes, often becoming as bright as about 100 million suns. Only a few supernovae have been observed in our own galaxy, and none have been detected since the invention of the telescope. But supernovae are often seen in other galaxies, and it is through study of these that astronomers seek to understand this violent stage of stellar evolution. Most supernovae are discovered through systematic searches of photographic plates taken with large telescopes.

But on the evening of April 18, Gus Johnson, an amateur astronomer in Swanton, Maryland, was routinely observing galaxies with his 8-inch reflector. Turning his telescope to M-100 (NGC-4321), a well-known spiral in Coma Berenices, he was surprised to see a bright object which he had not noticed before in that galaxy. It was a supernova.

Thus Johnson, a member of the American Association of Variable Star Observers (AAVSO), became the second amateur astronomer to have discovered an extragalactic supernova. According to Janet A. Mattei, Director of the AAVSO, the first was Jack Bennett of South Africa, who in 1968 discovered a supernova in the galaxy M-83.

Visual discovery of a supernova requires very careful and systematic observation, extreme familiarity with the appearance of galaxies, extreme perserverance, and a certain amount of luck in observing the right galaxy at the right time. Mr. Johnson, a teacher by profession, has been an astronomy enthusiast for about 20 years and a member of the AAVSO since 1974.

M-100 is a galaxy with a mottled nucleus and two prominent and several faint spiral arms, somewhat similar to our own galaxy, the Milky Way. It is about 40 million light-years away and has produced three other known supernovae, during the years 1901, 1914, and 1959. Johnson's supernova, located southeast of the nucleus on the inner spiral arm, is the brightest yet seen.(See photos on p. 39.) It quickly became brighter than the nucleus of the galaxy itself and was easily observable with a moderate-size telescope.

Johnson's discovery was confirmed by professional astronomers at McGraw Hill Observatory, Kitt Peak, Arizona, and Asiago Observatory in Italy, as well as by several amateur astronomers who are members of the AAVSO. The discovery was formally announced in the Astronomical Telegrams of the International Astronomical Union, which are issued from the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts.

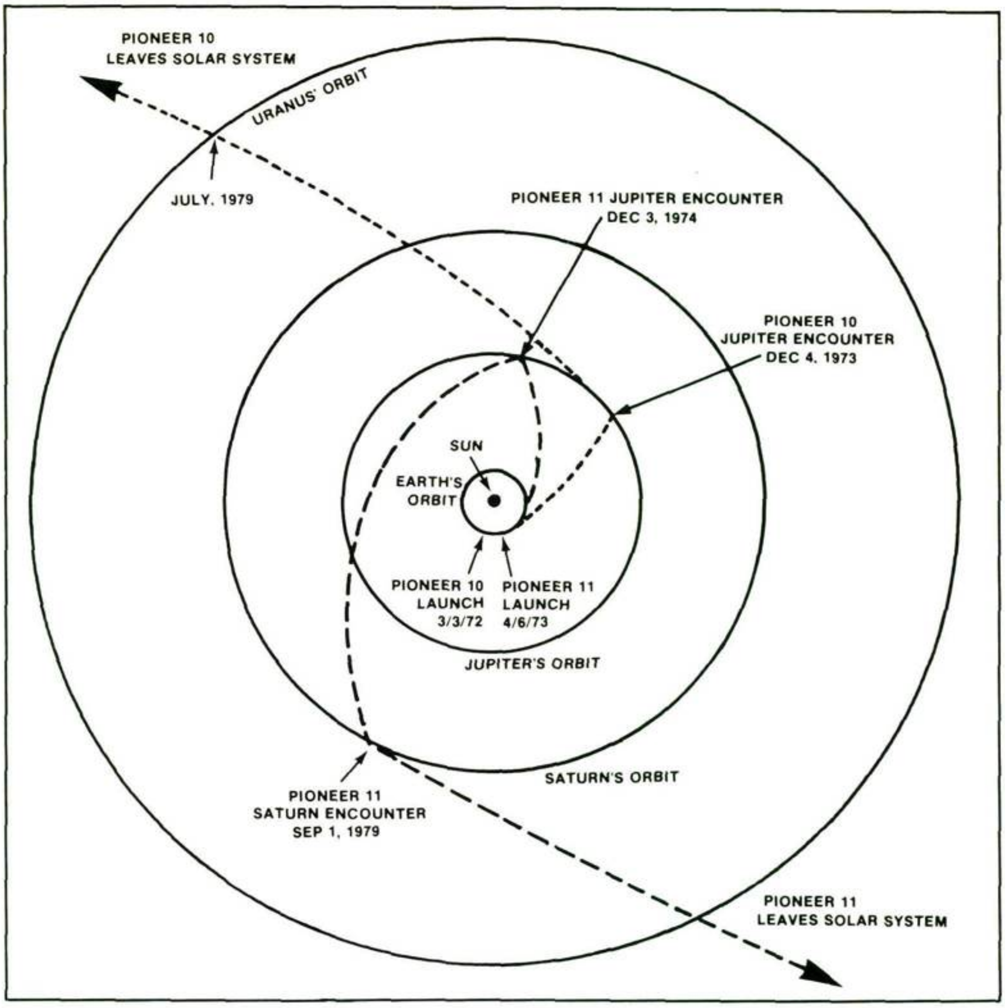
The AAVSO is a non-profit astronomical association devoted to the study of variable stars — stars that change in brightness. Its 1100 members, distributed worldwide, are mostly amateur astronomers. The association has records of over 4 million observations, the largest collection of variable star data in the world, and the data are used extensively by professional astronomers.

Solar System Pioneers

Two Pioneers are currently exploring the outer reaches of the solar system: Pioneer 10 and Pioneer 11, identical American spacecraft launched on the first missions to Jupiter and Saturn. (Both spacecraft reached Jupiter — in early December of 1973 and 1974 respectively.)

Now the first close-up investigation of the planet Saturn has begun, as Pioneer 11, launched in February of 1973, nears the second largest planet in the solar system after a journey of 6½ years. Closest approach is scheduled for 9:34 a.m. (all times are PDT spacecraft time) on September 1, when Pioneer 11 will swing only 13,300 miles above Saturn's clouds.

A number of other encounters are also planned, with several of Saturn's moons as well as the rings. Phoebe, the outermost moon, will not be an object of close study as the spacecraft will be nearly six million miles away at closest approach on August



27. On the next day, Iapetus will be seen from a range of 644,000 miles. Early in the morning of August 31, Hyperion will be examined from a distance of 418,000 miles. After August 31, Pioneer 11 will be too near Saturn for imaging of the full disk, and mosaics will be necessary to show the entire planet.

The most critical time of the mission comes at 7:35 a.m. on September 1 when the spacecraft is scheduled to cross the ring plane for the first time. We don't know how much debris may be spread out along the plane, but scientists are hopeful that the trajectory chosen will avoid any real danger to the spacecraft.

Pioneer 11 will fly past five more satellites on September 1 as well as swoop "under" Saturn's rings. The five, together with their times of closest encounter and range, are: Dione - 9:04 a.m., 180,000 miles; Mimas - 9:27 a.m., 64,000 miles; Tethys - 11:28 a.m., 206,000 miles; Enceladus - 11:33 a.m., 140,000 miles; and Rhea - 3:34 p.m., 212,000 miles.

Titan, Saturn's largest moon and the only satellite known to have an extensive atmosphere, will be imaged on the way out of the saturnian system, with closest approach coming at 11:05 a.m. on September 2 at a range of 221,000 miles.

ASTRONOMY will provide a complete, on-the-spot report of the historic encounter together with the best images returned in its November 1979 issue. Preliminary coverage will appear in the September and October issues.

Pioneer 10, the first manmade object destined ultimately to leave the solar system forever, crossed the orbit of the planet Uranus in July. The spacecraft did not pass anywhere near the seventh planet itself, for at the time of crossing, Uranus was on the opposite side of its orbit, nearly 180° away from the spacecraft.

The 570 pound probe continues to perform well, returning valuable data about characteristics of unexplored space in the distant outer solar system. Pioneer 10, launched on March 3, 1972, was the first spacecraft to approach and investigate Jupiter, making its flight past the giant planet in December of 1973. Saturn's orbit was crossed by Pioneer 10 in February 1976, but that planet was far away at the time.

Pioneer 10 will reach the expected limit for radio communications about the time it crosses the orbit of Pluto in 1987. Once it leaves the solar system, its radio signals will be too faint to be detected at Earth, although its nuclear power source is expected to last for several more decades. Later it will leave solar-influenced space altogether, crossing the boundary into interstellar space.

Pioneer 10 is headed generally in the direction of Aldebaran (Alpha [α] Tauri). Its actual pathway among the stars cannot now be calculated because scientists don't yet know enough about the exact space motions of the stars. Statistical calculations indicate that on the average Pioneer 10 will enter or pass near a stellar system, perhaps one with planets, about once every million years.

Both Pioneers carry plaques with an explanatory message about their origin for any intelligent species that might chance to intercept the spacecraft during their lengthy journeys through the galaxy.

Standard Shuttle Instruments

The new NASA budget includes starts for the first two candidates in the multi-user instrument facility. They are the solar optical telescope and the cryogenic limbscanning interferometer (CLIR), both being developed under the auspices of Goddard Space Flight Center.

The solar telescope will be a 50-inch f/3.6 reflector with a resolution of 0.1 arc second at 5500 A. Although light from the Sun does not seem to suffer from the same atmospheric effects that hamper astronomers, the problems are still there. According to Goddard, "observations presently attempted with great difficulty over many months on the ground will be made from space in a few hours with greatly improved resolution." The telescope will be mounted on a Spacelab pallet and take about one-half the length of the payload bay.

CLIR will permit detailed remote sensing of the Earth's atmosphere between 12 and 90 miles altitude. The radiometer will have a vertical resolution of a little over a mile. The interferometer will measure atmospheric emissions where high spectral resolution is needed, but low spatial and temporal resolution is acceptable. The 25-channel radiometer will give refined altitude and temporal resolution, but only low to moderate spectral resolution. CLIR, like the solar telescope, will be pallet-mounted and take about half the payload bay length.

A new start was sought but denied for the chemical release module which would allow the Shuttle to inject chemicals (metal vapors, gases, etc.) into the atmosphere. Unlike the sounding rockets that now do that task, the Shuttle would have the entire globe within its reach without requiring new launch facilities.

Other standard instruments under study include:

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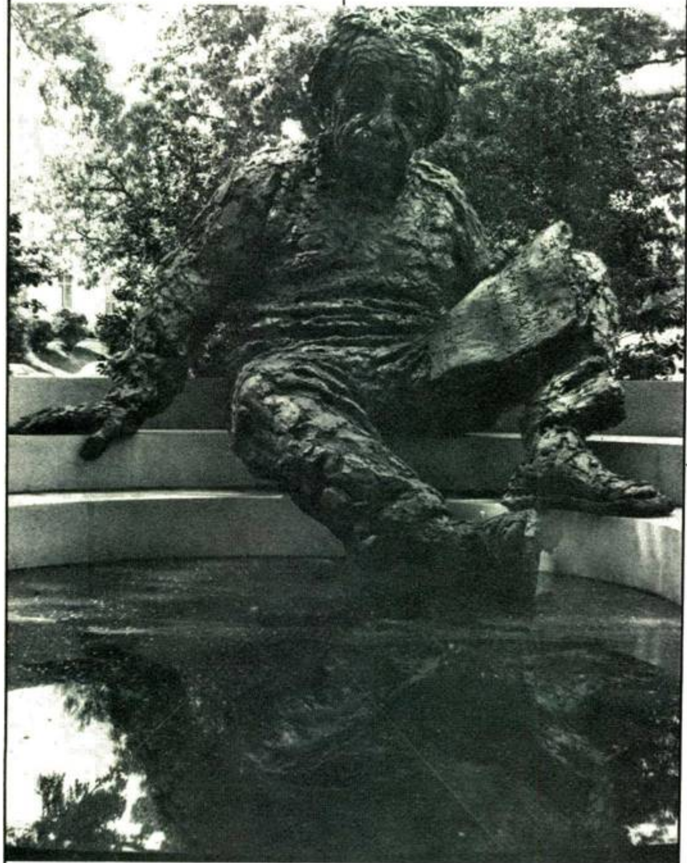
- The Shuttle infrared telescope facility, a 72-inch telescope using super-cooled mirrors and sensors for imaging and spectrographic studies with a sensitivity 1,000 times greater than any IR astronomy instrument in use or being built.
- A large area, modular array for high sensitivity and high resolution X-ray mapping. This would be similar to the smaller, less sophisticated A-1 experiment on the first High Energy Astronomical Observatory (HEAO-1).
- A laser-ranging instrument to study particles and aerosols in the upper atmosphere.

"These instruments will be operated similar to ground-based astronomy observatory programs," said Dr. Noel Hinners, NASA's outgoing associate administrator for space science, "in that proposals to utilize these instruments will be solicited and selected on a competitive basis. The existing Spacelab announcements of opportunity will be used for this process. In this way, many investigators will be offered the opportunity to utilize these large instrument facilities to collect data and perform their own experiments with specialized focal-plane instruments."

Einstein Star Chart

Thousands of years in the future, people may come to a place in what is now Washington, D.C., to ponder the patterns of the stars as their long-dead ancestors knew them. A controversial, 21-foot bronze statue of Albert Einstein, commissioned by the National Academy of Sciences to celebrate his centennial year, overlooks the largest, most accurate star chart in the world. The huge circle of dark granite, sandblasted with a band representing the Milky Way and inlaid with stainless steel studs, depicts the universe as seen from Washington at 12:00 noon on April 22, 1979, the day of the statue's unveiling.



A giant bronze statue of Albert Einstein sits in Washington, D.C., contemplating a huge star chart laid out in the granite pavement below him. Written on the scroll he holds are three of his most important equations, including the famous E = mc². The star chart is 28 feet in diameter, and the statue of Einstein measures 21 feet. Photograph by Michael Lee.

The 28-foot chart is constructed of 22 pieces of granite, grooved and fitted together to form the lines of an astronomical grid centered on the North Pole. Among the celestial objects represented are 2700 sixth magnitude stars, the Sun, Moon, Mercury, Venus, Mars, the asteroids Ceres, Pallas, Vesta, and Juno, double stars, star clusters, galaxies, nebulae, pulsars, and quasars. So accurate is the chart that each stainless steel stud is positioned with an error of less than 1/5,000 of an inch.

Robert Berks, commissioned to build the monument, worked with astronomers P. Kenneth Seidelman and Richard E. Schmidt of the United States Naval Observatory who calculated how the sky would appear at noon on April 22 using computer printouts to plot the various celestial objects. They chose the daytime sky so the Sun could be used along with the stars for dating. Using 72 templates, color coded and sized according to each star's brightness, holes were drilled in the stone slabs and fitted with studs whose edges were carefully beveled so that the stars appear to twinkle no matter where an observer stands.

Because of the durable materials used, the chart is expected to last at least 5000 years, allowing future generations to calculate the exact moment the statue was dedicated.

The Largest Spiral Galaxy

Our own galaxy, the Milky Way, is a large spiral galaxy about 100,000 light-years across, containing some 100 billion stars. A group of astronomers from the Carnegie Institution and the National Radio Astronomy Observatory have now identified the most massive spiral galaxy known. It is NGC-1961, an 11.5 magnitude galaxy located in Camelopardalis (1975: RA $5^h39.4^m$, Dec. +69°22′). Its total mass is estimated to be greater than 2 trillion suns — more than 10 times the mass of our own galaxy — with a diameter of 300,000 light-years.

NGC-1961 may have had a tremendous burst of star formation about 200 million years ago, a recent event on the astronomical scale. "This burst of star formation might have been caused by interaction or merger of NGC-1961 with a less massive galaxy," one scientist said. "The chaotic appearance in one region of the spiral structure supports these conclusions."

Slow-Spinning Asteroids

Asteroids, mostly small, irregular objects, often show differences in magnitude as various sides are presented to our sight. Photoelectric observations of regular variations in an asteroid's brightness can reveal its period of rotation. By far the great majority so far measured have short rotation periods, usually less than 24 hours.

But two asteroids, 128 Nemesis and 393 Lampetia, have now been found to have the longest rotation periods yet determined. According to a report in **Icarus** (January) by F. Scaltriti and V. Zappala of the Observatory of Torino, Italy and H.J. Schober of the Institut fuer Astronomie, Graz, Austria, 128 Nemesis rotates in 39.0 hours while 393 Lampetia has a somewhat shorter period of 38.7 hours.

The team also reported that tiny variations in the magnitude of 128 Nemesis indicated the presence of "small-scale surface features," representing mountainous lumps about 10 miles high and 10 miles wide on the surface of the 100-mile diameter asteroid.

Enemy Light

Virtually everything astronomers know about the distant stars and galaxies has been discovered by gathering and analyzing the light and other forms of electromagnetic radiation they emit.

But light can also be an enemy. Extraneous outdoor lighting at night has become such a problem in North America and elsewhere that professional and amateur astronomers now refer to the phenomenon as "light pollution." There is a deep and widespread concern among astronomers that research at observatories on even the darkest mountain tops in the 48 contiguous United States is being affected adversely by light pollution.

The general public may not be especially concerned right now about the scientists' problems, but they should be, according to Arthur Upgren, Associate Professor of Astronomy at Wesleyan University.

Upgren thinks people should be worried because the same outdoor lighting that perplexes the astronomers costs a great deal of money to produce. Upgren, who has made it his business to keep informed about light pollution, says 20% of all the electric power generated in the U.S. today is used for outdoor lighting. What's worse, in his view, is that outdoor lighting is the fastest growing component of all of the nation's drains on electric power. "If we need to build more nuclear power plants during the next ten years, it will be to meet the demands for outdoor lighting," Upgren says.

In terms of power usage, outdoor lighting in the U.S. is growing at the rate of 10% per year. In terms of actual light produced, the annual rate of increase is 20%, due to technological advances that make it possible to obtain more light per unit of power. At this growth rate, in which outdoor lighting would double in brilliance every four years, the United States' night-time sky would be 30 times as bright in the year 2000 as it is now. Already cities of population 35,000 are easily visible in photographs taken at night by satellites. In these photos the megalopolises appear as broad patches of light.

Most of the urban lighting installed recently has been in response to the public's perception that increased outdoor illumination deters burglaries, rapes, and other criminal acts, Upgren says. He notes that outdoor lighting and crime curiously have been increasing at the same rate, but says he is not able to comment on the veracity of some studies which indicate increased lighting does not deter crime.

Commenting on President Carter's recent call for restrictions on outdoor lighting for advertising, Upgren says advertising is not nearly as serious a problem as overall outdoor lighting. In fact, Upgren points out that the single largest user of electricity in New England is not outdoor advertising, but the skiing industry, which uses vast amounts of energy to illuminate slopes for night skiing and to make artificial snow. "I think I can safely say that more energy is wasted in the pursuit of physical fitness than in creature comforts," Upgren says.

The major observatories whose large telescopes peer into deep space were the first to sense the light pollution problem, as it takes only a small amount of extraneous light to affect their instruments. More recently, the American Astronomical Society and the International Astronomical Union established committees to investigate the problem and call attention to it as more and more sites become affected.

Tucson, Arizona, was the first city in the nation to respond in a positive manner to the astronomers' concerns. Tucson enacted a strict ordinance in 1972 requiring all new outdoor lights to have shields that extend below the horizon and to have filters to block certain wavelengths that interfere with astronomical photography. Tucson's reason for concern is that three major observatories lie nearby on Kitt Peak, Mt. Lemmon, and Mt. Hopkins, and they are a matter of regional pride.

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Upgren hopes the Tucson ordinance will become a model for other communities, but few other cities have taken steps to control outdoor lighting. Upgren suggests that light pollution is even more serious to astronomers in the eastern United States, where there are many fewer cloudless nights than in the West.

Even on a clear moonless night there is a slight amount of natural illumination from stars, the Milky Way background, and the interaction of charged particles in the atmosphere. Upgren found that the night sky in the vicinity of Van Vleck Observatory at Wesleyan is 18 times brighter.

From measurements he has made in Middletown, Connecticut, Upgren has determined that immediate local sources of light are a much greater factor than are distant cities in contributing towards light pollution, except in areas where the distant cities are the *only* sources of extraneous light.

Upgren is trying to bring outdoor lighting under control at his own campus before he extends the battle elsewhere. "We'd like Wesleyan to be a model for the community regarding control of light pollution. We can't expect sympathy and cooperation from local officials unless we start at home," he says.

Until recently, astronomical work at Van Vleck Observatory was hindered by some very bright security lights near Wesleyan's Andrus Field. Upgren learned from their manufacturer that they are rated at 100,000 candlepower each, making them brighter than all but five lighthouses on the Great Lakes and ten times brighter than the full moon as seen from the observatory. Simply by re-aiming some of these lights, Wesleyan was able to reduce most of their interference with the astronomy programs. The University also gave the astronomers control over ten of the sodium vapor lights nearest to the observatory so that they may be turned off when classes are viewing constellations or when other work is in progress.

Upgren says he is pleased that the Wesleyan administration has begun to recognize the problems light pollution poses to astronomy, but his goal is to make the general public aware of the problem and its ramifications in terms of energy demands.

He says light pollution studies could have applications to disciplines other than astronomy. Having noted a correlation between the amount of light produced by an urban area and its population, he suggests that light-level data could be used by demographers to re-define population centers in metropolitan areas.

Measuring light outputs also could be used as a measure of prosperity and technological advancement (or technological extravagance) in different areas of the world. Upgren says he would expect a city of a million people in the United States, for example, to have much higher levels of outdoor illumination than a city of one million in Latin America, indicating a much higher level of energy consumption. "Excessive outdoor lighting could be bringing on the very nuclear contamination that many people hope to avoid," he says.

Highly Active Sun Forecast

The occurrence of sunspots varies in cycles averaging around 11 years — twenty cycles have been observed since 1755. We are now approaching the maximum in Cycle 21, the minimum activity having occurred in 1976. The highest maximum number of sunspots observed was 201, in Cycle 19 (March 1958).

Radio communications, especially in the 3 to 30 megahertz (high frequency) band, are vitally affected by sunspot activity, with long-distance propagation increasing dramatically as the cycle approaches its maximum. Because of this, a number of investigators have made predictions of sunspot maxima for Cycle 21 and the times of their occurrences.

Predicted maxima range from as low as 60 to highs of up to 200, to occur in the years 1979 to 1984. Published during the past two sunspot cycles, these predictions were made on the basis of a pattern analysis of the sunspot numbers alone.

A major limiting factor in the success or failure of predictions is the size of a reliable data base containing at best 11 sunspot cycles. Data prior to 1848 are considered to be unreliable. The first seven cycles starting from about 1755 have been noted to differ statistically from the subsequent cycles, so some investigators use only the later cycles in constructing an average solar cycle.

Scientist H.H. Sargent III of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), has recently summarized a number of predictions of the time and intensity of Solar Cycle 21. Working in NOAA's Space Environment Laboratory in Boulder, Colorado, Sargent has analyzed the method of A.I. Ohl in predicting the maximum level of sunspot activity (154 in 1980). The prediction is unique in that its value for Cycle 21 is considerably higher than most of those made in recent years by a number of other investigators.

The method used to make the prediction was founded on a data base of only 11 sunspot cycles. This was because geomagnetic data not available prior to 1868 were used.

It was considered that the cycle of geomagnetic activity which accompanies each sunspot cycle may be separated into two components. One is a sporadic component associated with large solar flares, and the other a recurrent component thought to be caused by high speed solar wind streams. It was found that the size of the recurrent component is closely related to the maximum value of the succeeding sunspot cycle.

There is less than one chance in a thousand that the relation developed is one of mere chance, convincing evidence that magnetic activity in the declining phase of one sunspot cycle is somehow physically related to the level of solar activity during the next cycle. Using this equation, the past 3 sunspot cycles would have been predicted within 5% and several would have come within 1% of the observed values.

A careful examination of Cycles 10 through 20 showed that the even-numbered cycles were different in appearance from the odd-numbered cycles; as each cycle proceeded to its maximum value, even-numbered curves are more truncated while the odd-numbered rose rather deliberately to maximum. This suggested two different families of cycles. An average odd-numbered cycle was constructed from the 5 odd-numbered cycles (Cycles 11-19) and rescaled between the last observed minimum (12.2) and the predicted maximum value for Cycle 21 (153.6). This made possible the prediction of the monthly values for Cycle 21 and the predicted maximum value falls in early 1980.

Also, analysis showed that the 3 largest cycles had the steepest increases while the smaller cycles proceeded less steeply from the minima. Each cycle settles down to a smooth and steady upward pace within about 18 months after solar minimum and the upward slope of Cycle 21 had become well-established in the first few months of 1978. This feature should make it possible to confidently predict the maximum value of Cycle 21.

The effects of high sunspot activity on radio communications, especially in the high frequency (3 to 30 megahertz) part of the spectrum and the lower end of the very high frequency band (30 to 300 megahertz), would have both advantages and disadvantages. More than 350,000 licensees of the Amateur Radio Service — Hams — will find it possible to conduct extremely consistent, long-distance communications frequently and with relatively low power.

On the other hand, radio operators confined by law to specified frequencies may find them more heavily congested than at the present time, making them much less efficient as methods of intelligible communication. This is generally the case with increased solar activity.

But there are ways such high activity can temporarily worsen propogation conditions. Solar flare events, related geophysical aspects, and geomagnetic and ionospheric storms can disrupt radio communications for periods of a few minutes to several days. If Cycle 21 is as large as predicted in this analysis, relatively more of such major disruptions can be expected.

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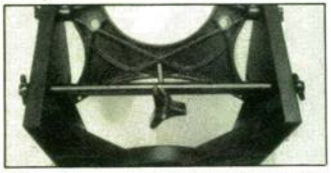

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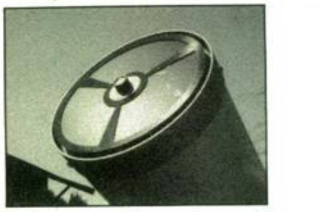

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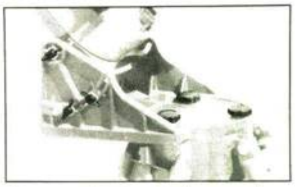

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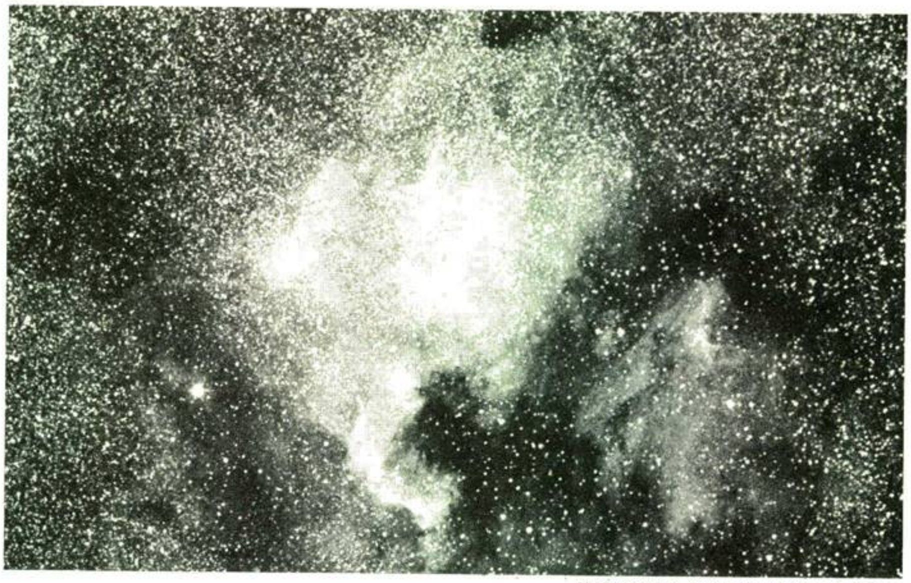

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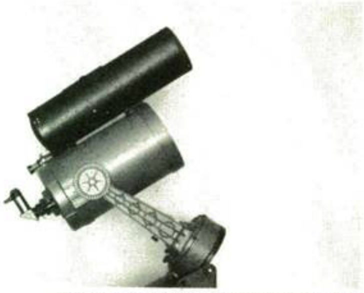

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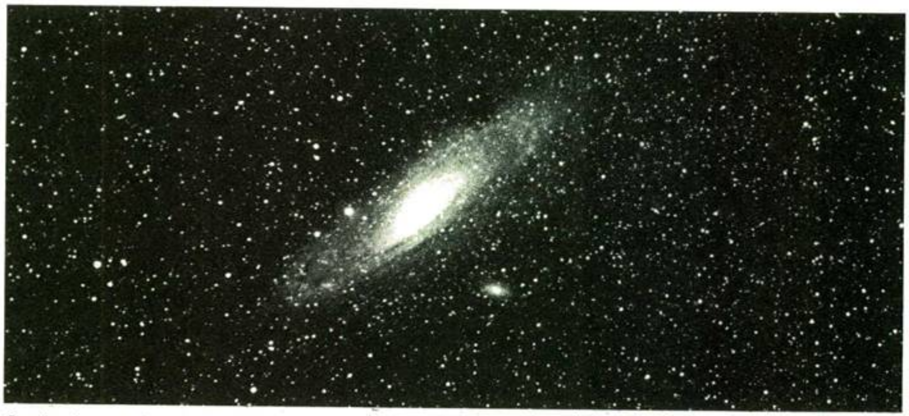

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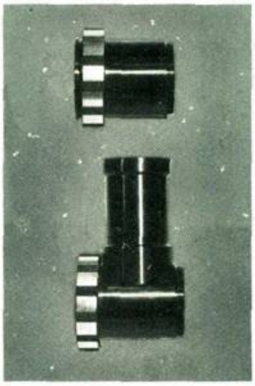

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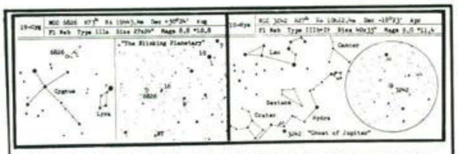

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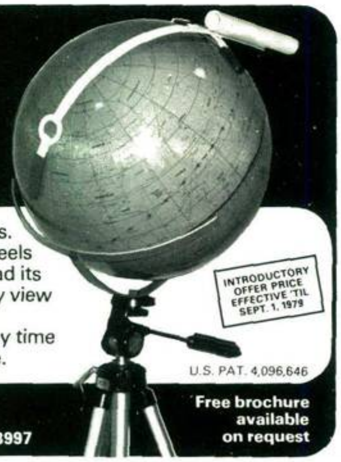

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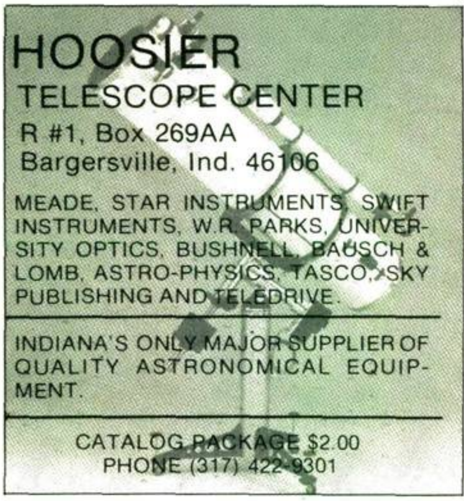

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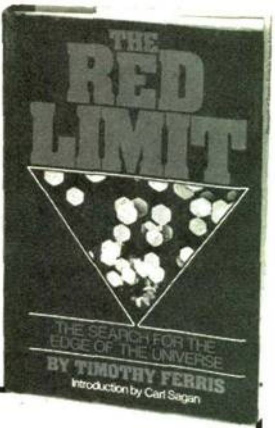
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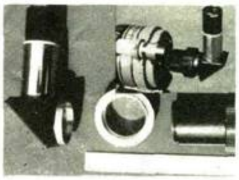

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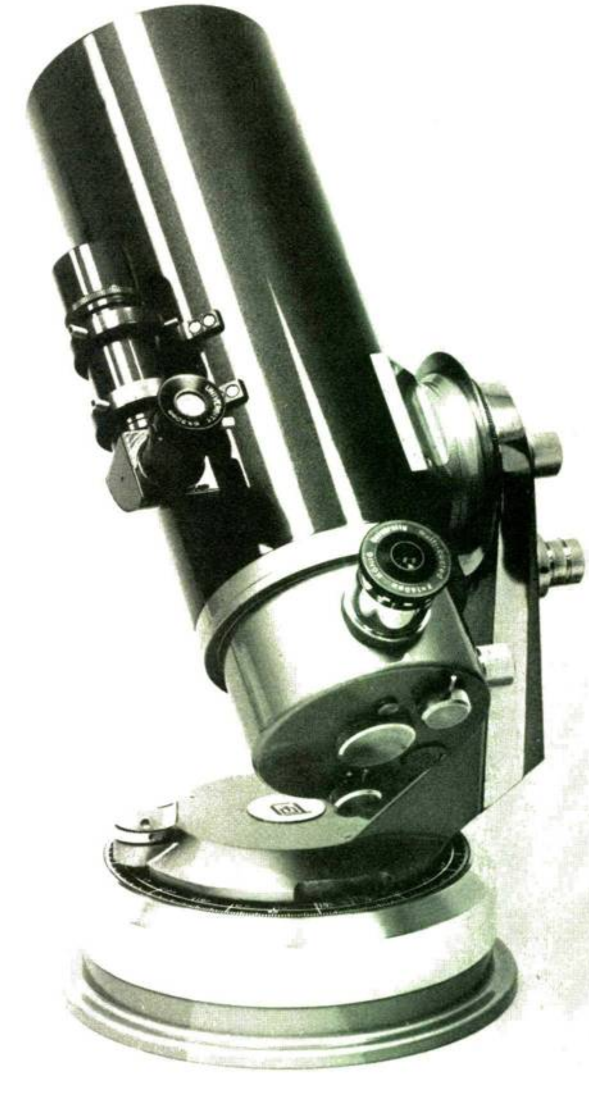

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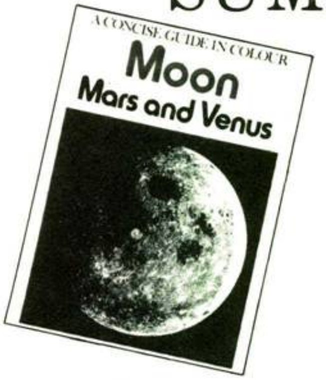

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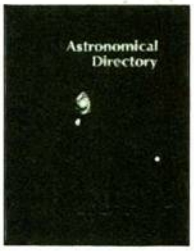

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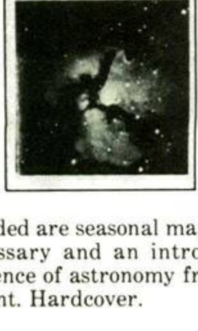

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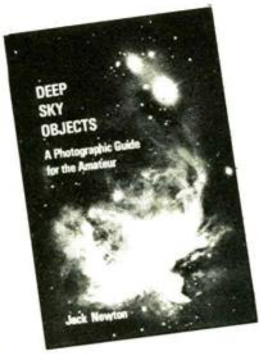

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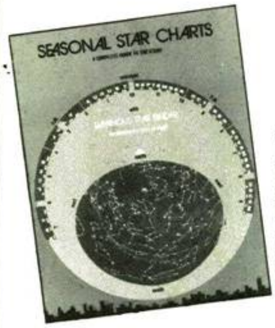

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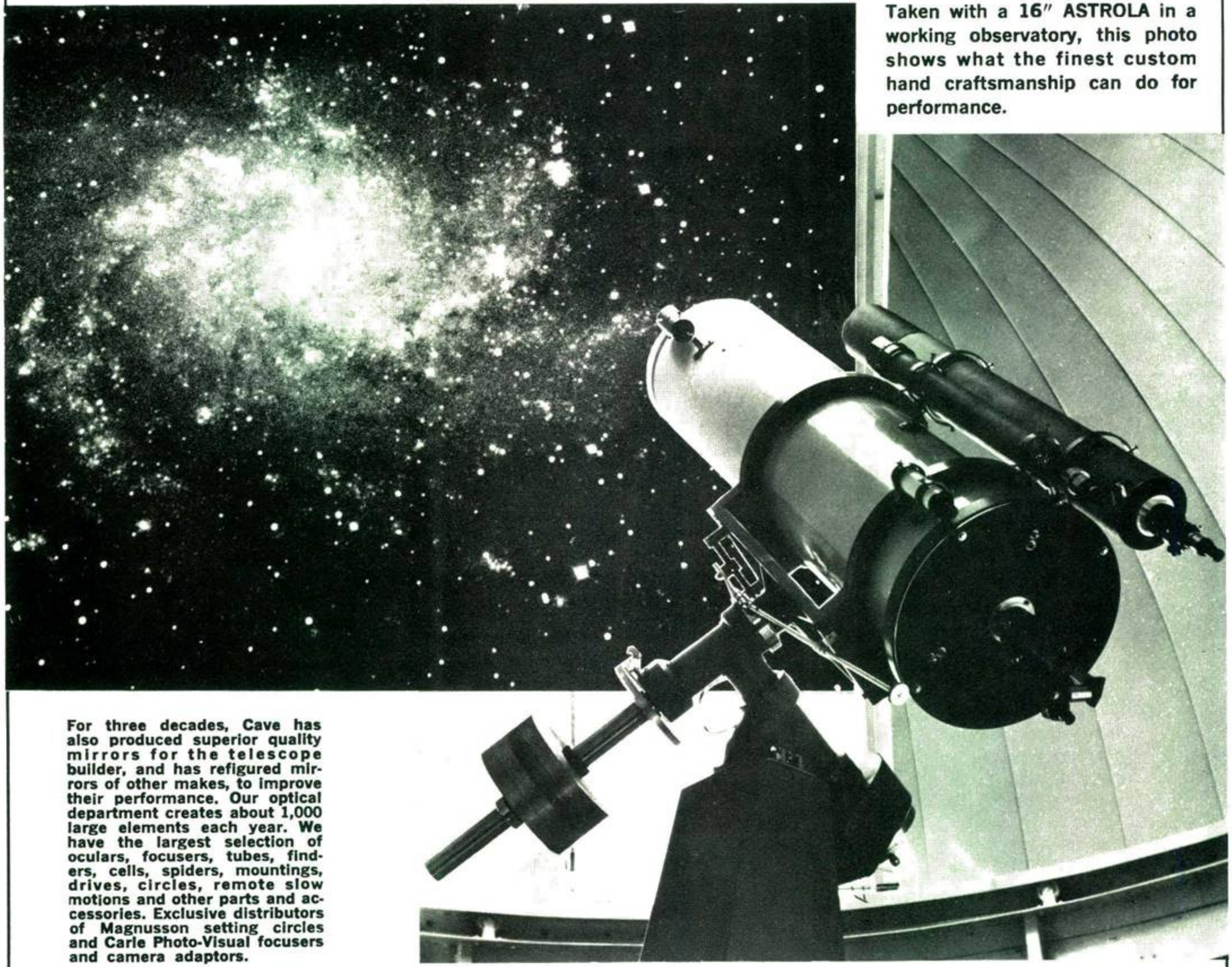

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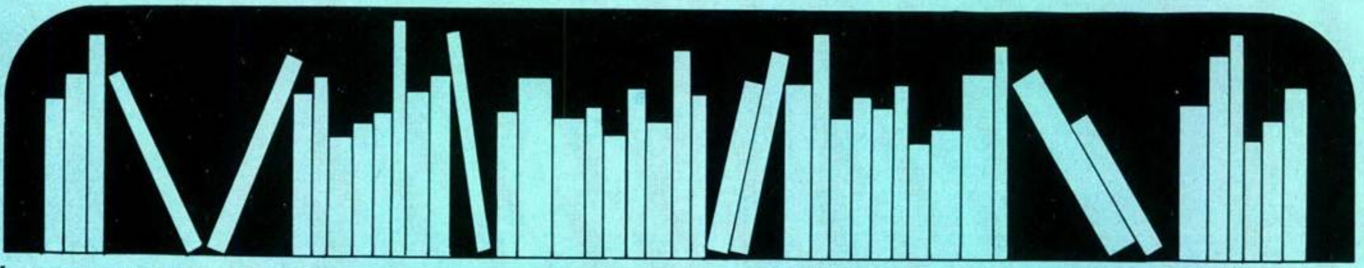

ASTRONOMY REVIEWS

Cosmic Evolution: An Introduction to Astronomy

by George B. Field, Gerrit L. Verschuur and Cyril Ponnamperuma

450 pages (illus.), hardcover, $14.95
Houghton Mifflin Co. (1978)

The word "evolution" is usually thought of in connection with biology, but astronomers also use the term. They talk about the evolution of stars, galaxies, and even the evolution of the universe. We might ask, then, if there's a link between the evolution of life as it is known to the biologist, and the evolution of the universe. In other words, do we have a complete (or nearly complete) picture starting with the evolution of the overall universe and ending with the evolution of man? **Cosmic Evolution** tries to answer this question.

Although it's written in the format of a textbook, it is clearly different from most introductory astronomy texts. Basically, astronomy is approached through evolution. The authors had originally hoped to begin with the Big Bang explosion and follow through to the emergence of man, but they found that this would entail numerous side explanations and footnotes, so they eventually abandoned this route. They compromised by covering briefly most of the topics of a traditional astronomy course first (for the necessary background), then going on to a discussion of evolution.

Because of its rather unorthodox approach, the book would be best suited for a specialized astronomy course — one with a strong emphasis on exobiology. It would probably not be appropriate for the usual liberal arts astronomy course.

The goal of the book is to give an up-to-date account of the evolution of the universe (and its contents) beginning with the Big Bang explosion. The authors succeed quite well in accomplishing this goal. They start off with a better-than-average chapter on the Earth, and follow it with brief but adequate chapters on the Sun, Moon, planets and stars. Chapter eight completes the first phase of the book with a discussion of galaxies and the universe.

Phase two, with its emphasis on evolution, begins at chapter 10. The order of topics is now reversed with the evolution of the universe being treated first. From here the authors go to the galaxies, the stars, the solar system, Earth and finally to life itself. The last few chapters (with the exception of the last) are all biological in nature.

The material on cosmology and some of the sections on evolution are quite good. A number of topics (i.e., effects of magnetic fields and rotation in star formation) are included which are not generally found in other similar texts. The sections on stellar evolution are about average; the last chapters on exobiology, on the other hand, are definitely above average.

Each of the authors is well known in his respective field. Cyril Ponnamperuma is a leading expert in exobiology, George Field has published extensively in cosmology and Gerrit Verschuur is well-known as a ranking astronomer (among other things).

The book should be comprehensible to anyone approaching the subject for the first time. There is no mathematics in it, except for a small amount in the appendices. The last few chapters place a considerable emphasis on biology, but they are not difficult to read.

There aren't as many illustrations in it as in most similar elementary astronomy texts, but this doesn't necessarily detract from it. Constellation charts are given on the inner covers (they could be bigger). Also, there are a number of color photos in the center, each accompanied by a lengthy caption. And at the end of each chapter there's a summary, a number of "thought questions," and a glossary. They are unquestionably a positive feature.

Overall, the book is accurate, well written and would no doubt be indispensible if used in the right kind of course. *Barry Parker.*

◆

The Martian Landscape

by the Viking Lander Imaging Team

160 pages, hardcover, $12.00*
NASA SP-425 (1978)

This stunning volume is NASA's first major report to the public on the Viking mission. It contains over 200 magnificent Mars photographs arranged and specially processed by Ken Jones (pictured on page 26 wearing a Viking helmet). Most of the pictures are black and white (25, including the cover picture, are in color), but it's a beautiful, richly reproduced, large-size black and white. Most of the images were taken during the primary mission, and show, in great detail, both lander sites at different times of the day. This organizing principle, showing the same scene under early morning light, full noon light, and late afternoon light, adds depth and interest to these martian scenes that a single-shot, one-time-of-day organization could not possibly show. You'll find yourself poring over one of the groups of three, finding and comparing each rock, dune, shadow, or glint of sunlight with the other two lightings.

Imagine spending a day at two locations in a desolate rock-strewn desert photographing the scene all around you — your feet and the rocks beside them, sunrise, sunset, and a few small holes dug with a trowel — then returning home to publish a book of photographs. **The Martian Landscape** is exactly that: the two lander sites, photographed very thoroughly, filling an entire book. The difference, of course, is that the place is Mars.

The first 32 pages are written by Imaging Team leader Thomas Mutch. It's a semi-personal story of the Viking cameras, of the ten years he spent involved in the Viking mission, the formidable engineering problems of sending a "fax" camera to Mars, even the problems of testing the cameras on a real desert scene — primarily a bureaucratic problem, but formidable nonetheless.

After the introduction, the picture section begins. The pictures are generously large — large enough that you don't feel you're missing anything. Every pebble and every grain of sand seems to be visible. It's not difficult to slip into feeling that you're really there. The picture commentary is low-key and easy to understand, though occasionally a bit of geologist's jargon manages to slip in. But how else can you describe such geological scenes? The most impressive pages are 40 and 41: a two-page, black and white spread showing the "Big Joe" panorama twice. In one version, it's backlit by the early morning sun; in the other, it is illuminated by late afternoon light. At the right, drifts of sediment look strikingly like terrestrial sand dunes; throughout the scene, oddly sculpted rocks jut from the ground. Big Joe sits there, enigmatically dust-covered.

The color pictures are less striking than the black and white, generally lacking the crispness that makes the rest of the book so exciting. However, read the account written by the imaging team of reproducing the martian scene "as it would look to us," and you'll begin to understand what a feat it is to return color pictures from another world.

Finally, as an unexpected surprise, there are 19 stereo photographs and a stereo viewer included with the book. Suddenly the true character of the rolling landscape of Mars becomes reality. The ground, rock-studded, is gently rolling, with pockets of drift and occasional bedrock — it's a place and a landscape you can imagine walking right into. *Richard Berry.*

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Catalogue of Cometary Orbits

by Brian G. Marsden

88 pages, paperback, $4.00
Smithsonian Astrophysical Observatory (1979)
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Cambridge, MA 02138]

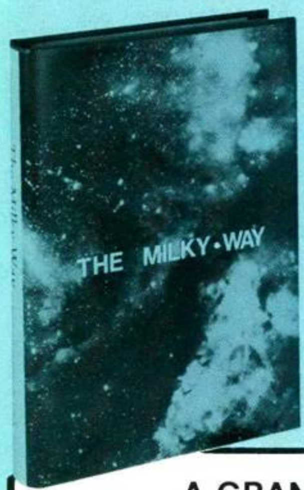
Now in its 3rd edition, this catalog is indispensible for anyone interested in comet orbits and meteor streams. 658 comets have their orbital elements tabulated, and appearances of them are listed complete through the end of 1978. There are several related tables giving names and dates of observability, and data on periodic comets.

Shuttle: the World's First Spaceship

by Robert M. Powers

255 pages (illus.), paperback, $10.95
Stackpole Books (1979)

If you've been thinking that the Shuttle just sort of happened, then you're in for a big surprise on looking through this book. Powers tells the story of its development from dreams and ideas to hardware. In addition, he shows what the plans are for its uses, many of which will involve scientist-astronauts from several countries.



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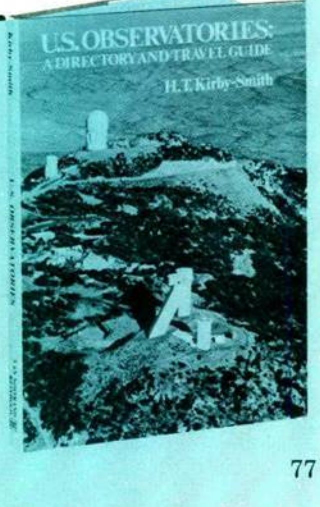

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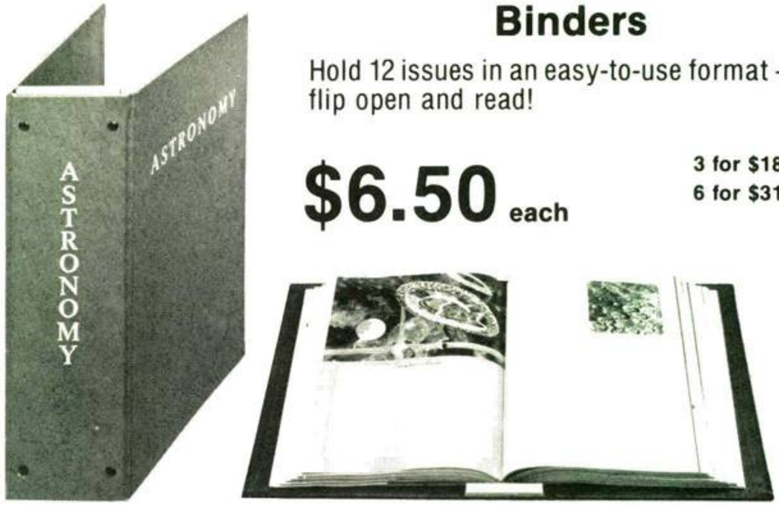

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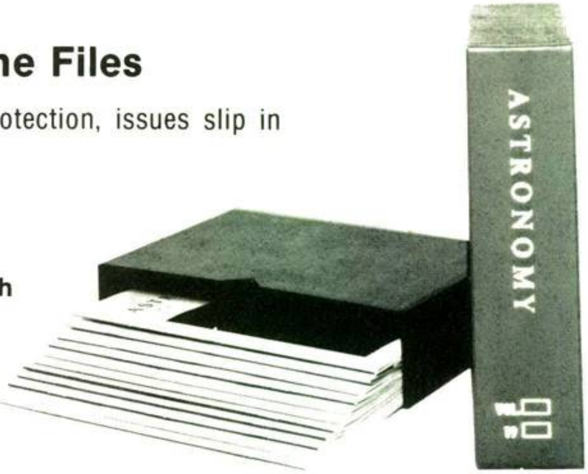

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STAR DOME

AUGUST

by

Dewey Schwartzenberg
and
James Mullaney

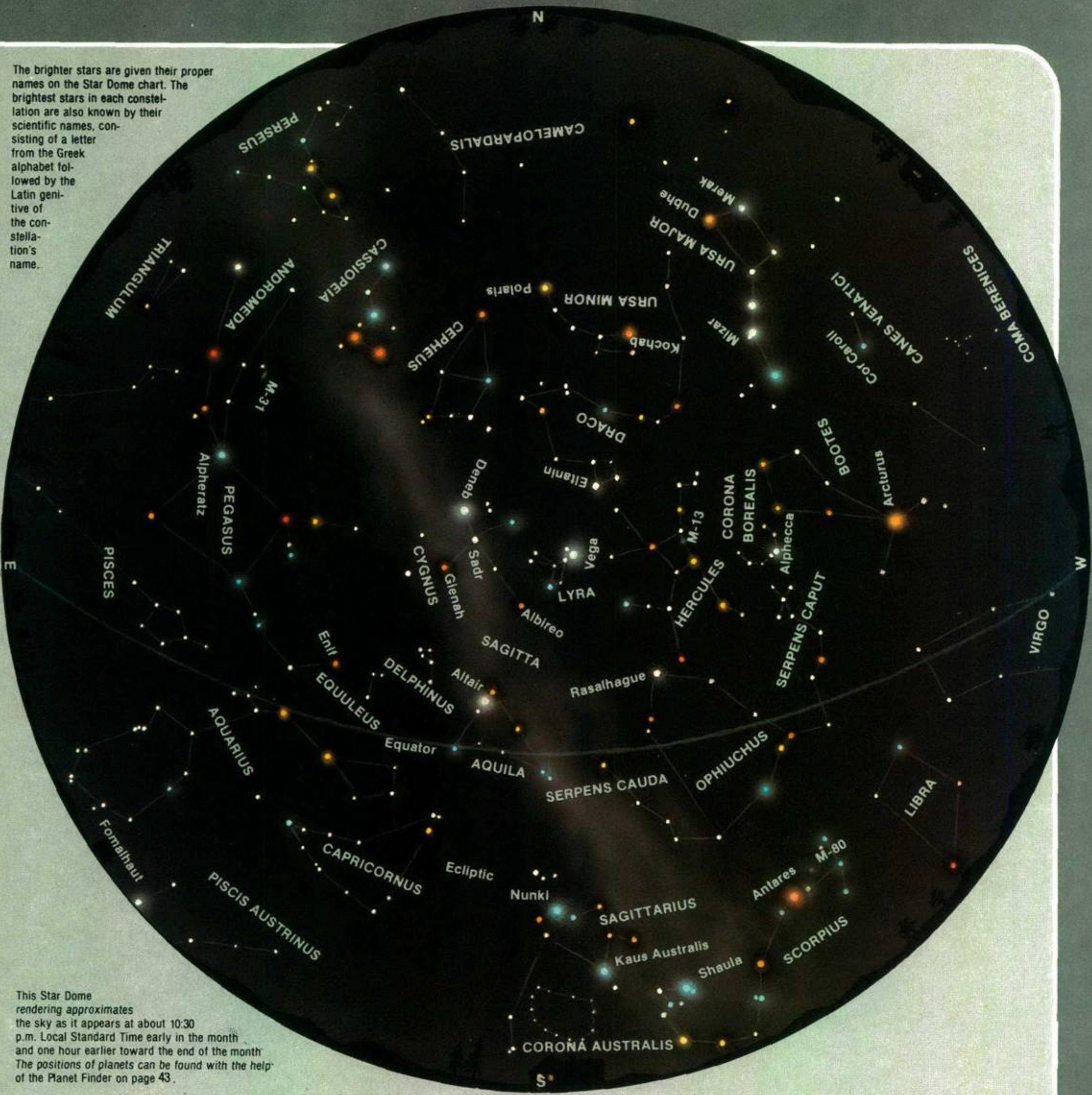
Much has been made recently of a number of possible celestial disasters befalling Earth and its inhabitants. Perhaps the most specious is the idea that a chance alignment of all the planets, supposedly occurring in 1982, will lead to violent storms and earthquakes on Earth. Unfortunately for those who, eagerly or otherwise, anticipate a 1982 doomsday, there is no sound scientific basis to the prediction.

First, the planets will not in fact "line up" in a dramatic **2001: a Space Odyssey** fashion — nor can they ever. According to the Nautical Almanac Office of the U.S. Naval Observatory, the closest upcoming alignment will occur on March 10, 1982, but even then there will be a spread of 60° in planetary positions — one-sixth of a full circle. Such an approximate "alignment" occurs only every 179 years for the eight main planets. If Pluto is included, a rough line-up takes place about once in more than 500 years, so the 1982 event will be interesting — but not physically significant.

This is because the planets have so little influence on either the Sun or the Earth. Even if all the planets were actually to be in line with each other, the tidal effect on Earth due to gravitation would be undetectable, much less cataclysmic. As we saw last month, the total mass of all the material in the solar system outside the Sun is just a bit over 447 Earth masses. The mass of the Sun itself on the same scale is 332,830 — nearly 750 times greater. It has been calculated that if all the planets were in the right position to raise maximum tides on Earth, the resulting force would be only one-ten-thousandth that exerted normally by the Moon and Sun. Not only would this have no effect, it would not even be detectable by the most sensitive scientific instruments.

But what about the effect of the planets on the Sun? It has been argued that planetary tides raised on the Sun trigger an increase in solar activity, which could then have an effect on Earth, triggering storms and earthquakes. Aside from the fact that the last link in this causal chain — that normal variations in solar activity influence Earth's weather and geophysics — is far from proven, the gravitational forces of all the planets in 1982 will combine to raise tides on the Sun of about one-fifth of an inch. There is no known mechanism, not even a "trigger" mechanism, by which such a tiny impact could have any physical effect whatsoever on the Sun.

In fact, more than 99% of even this tiny a solar tide is due to the gravitation of just four of the nine planets: Mercury, Venus, Earth, and Jupiter. The effect of Jupiter is of course due to its enormous mass, while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CAMELOPARDALIS
Merak
Dubhe
URSA MAJOR
TRIANGULUM
ANDROMEDA
CASSIOPEIA
Polaris
URSA MINOR
CEPHEUS
Kochab
Mizar
CANES VENATICI
Cor Caroli
COMA BERENICES
M-31
DRACO
BOOTES
Alpheratz
PEGASUS
Deneb
Eltanin
CORONA BOREALIS
M-13
Arcturus
Alphecca
PISCES
E
CYGNUS
Sadr
Gienah
Vega
LYRA
HERCULES
SERPENS CAPUT
W
Albireo
SAGITTA
VIRGO
Enif
EQUULEUS
DELPHINUS
Altair
Rasalhague
AQUARIUS
Equator
AQUILA
SERPENS CAUDA
OPHIUCHUS
LIBRA
Fomalhaut
CAPRICORNUS
Ecliptic
Nunki
SAGITTARIUS
Antares
M-80
PISCIS AUSTRINUS
Kaus Australis
Shaula
SCORPIUS
CORONA AUSTRALIS
S

The brighter stars are given their proper names on the Star Dome chart. The brightest stars in each constellation are also known by their scientific names, consisting of a letter from the Greek alphabet followed by the Latin genitive of the constellation's name.

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month and one hour earlier toward the end of the month. The positions of planets can be found with the help of the Planet Finder on page 43.

the three innermost planets, despite their low masses, contribute to the total because of their relative nearness to the Sun. Tidal forces decline with distance much faster than the inverse-square decrease in the gravitational force itself, so the contribution of even the other gas giants is truly negligible. But though Mercury, Venus, Earth, and Jupiter "line up" much more frequently than do all nine planets, no effect on solar activity has been conclusively observed during past such alignments.

If gravitational and tidal forces are not strong enough to have any impact, what about magnetic fields? Some have argued that fluctuations in solar and terrestrial magnetic fields have a direct impact on biochemical systems, leading to various diseases and even death in humans. If this were true, we should have a great deal to worry about, since those little magnets on our bulletin boards and refrigerators dump more magnetic flux into our bodies than the terrestrial and solar fields combined. And as for the influence of the planets, there simply is none. Before the advent of deep-space probes, we had no way to tell whether or not the other planets even had a magnetic field at all, so it is hard to see how such fields could have any terrestrial effects.

Are there any other forces, fields, or powers emanating from the planets which could affect our life on Earth in any way, by any conceivable chain of events? It is certainly the central tenet of astrology that such is the case. The only problem is that science knows of no such mysterious powers, nor has any scientific instrument ever detected any unexplainable force coming from the planets. It is hard to see how an unknown force could have a real physical effect on Earth without having any detectable physical effect on any scientific instruments. Those who believe in such things are always forced to fall back on the notoriously unsafe quicksands of statistical and empirical correlations, and even there,

no significant evidence for any such effects has yet been produced. When correlations are found, such as the fact that the incidence of heart attacks in the Russian city of Sverdlovsk over a twenty year period is directly related to the level of solar activity, we are not told in how many other cities such a correlation was not found, nor why it is that (for example) cancer deaths in the same city show no such correlation.

From time to time in this Star Dome introduction we discuss various celestial myths by which man has sought to render the sky and its wonders meaningful on a human level. Myths are never totally without truth, though the truth may be hidden behind the symbolic terms of the myth. A good myth of any kind always tells us something true about ourselves as well as helping us to feel at home in the cosmos, but this popular modern myth of a looming planetary disaster — about which we will undoubtedly hear a great deal more as 1982 approaches — reveals only the degree to which man is still bound by fear and ignorance.

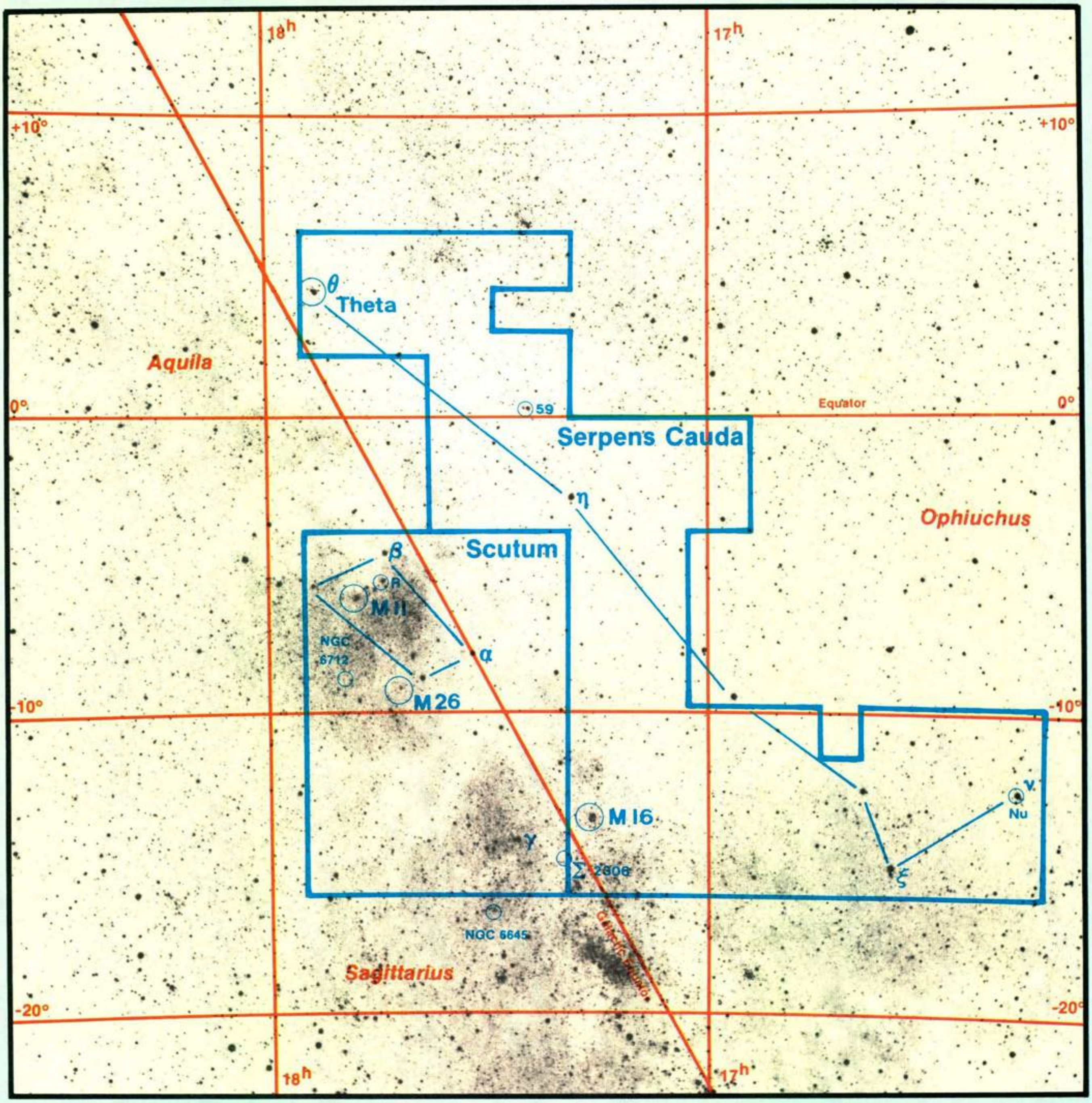
Close-Up

Serpens Cauda/Scutum

Completely enclosed — and almost overshadowed — by the prominent constellations Aquila, Sagittarius, and Ophiuchus, this month's region is often skipped over by visual observers. It comprises Serpens Cauda, marking the tail of the sky serpent (which lies east of Ophiuchus, the serpent bearer), and tiny Scutum, the celestial shield. Although the latter ranks 84th in size among the 88 constellations, it is the site of the magnificent Scutum star cloud of the summer Milky Way and offers superb sweeping on dark nights with binoculars and wide field telescopes. To explore this area of the heavens is to sense rare beauty.

Theta (θ) Serpentis

Nearly one hour right ascension west and 5 degrees of declination south of Altair — near the Aquila-Serpens border — lies this region's finest double star. This is Theta (θ) Serpentis, consisting of 4.6 and 5.0 magnitude suns some 22 seconds of arc apart in



position angle 103° (roughly east-west on the sky). It can be resolved as a double in a good finder or mounted binoculars, and is a lovely sight in even the smallest telescope. A 2″ glass at just 30x shows it perfectly.

Barns called this object an "imperial pair in regal setting" and Webb a "noble pair in a very fine field." Smyth gave the colors here as pale yellow and golden yellow, and most observers have agreed, logging the components as yellow, white, or yellowish-white. Both are A5-class suns and Robert Burnham, Jr. sees them as "clear sparkling white," adding that "Theta is one of the most attractive double stars in the sky for a very small telescope."

Muirden considered the members of this neat duo as only 0.2 magnitude apart in luster (4.0 and 4.2), and found it "a superb pair in a fine field." Theta appears on many observing lists including Flammarion's roundup of the 25 best doubles. Colas included it under the category of finest white double stars, as did Pickering — but only as a "runner-up" to his main roster of the sky's 60 best objects. Surprisingly, Bernhard, Bennett, and Rice omitted it from the excellent tabulation of double stars in their classic **New Handbook of the Heavens** — surely an oversight.

The components of Theta Serpentis have remained relatively fixed in the 150 years or so it has been under study by double star observers, but they very likely form a long period binary system. Both suns are definitely gliding through space together and lie at the same distance from us of 130 light-years. This visually stunning showpiece appears little-known to most modern stargazers — are you one of them?

M-26

Our next offering is one of three Messier objects residing in this month's region and one of the least observed of all entries in this famous catalog of deep-sky targets. This is the open cluster M-26 — a 9 arc minute wide bundle of some two dozen stars softly glowing near 9th magnitude. The noted comet and variable star observer John Bortle rates it at 7.7 visually from estimates made with binoculars. Look for it in your finder about a degree southeast of Delta (δ) Scuti or 1½° in the same direction from Epsilon Scuti. It also lies 3½° southwest of the bright cluster M-11, detailed below.

Webb described M-26 as a "coarse cluster" and Holyoke as a "fine open cluster but fainter and less compact than M-11." Muirden found it a "small cluster, consisting of a few bright stars seen against a haze of fainter ones." Mallas' impression was: "The 4-inch refractor reveals more than 20 stars arranged roughly in the shape of a fan. In very clear skies, fainter stars are seen on an uneven background."

Like its spectacular and well-known neighbor M-11, M-26 is embedded in the dense strata of the Scutum star cloud. Both clusters also happen to lie at nearly the same distance from us of about 5,000 light-years. This means the difference between the two objects in size, brightness, and number of stars seen visually at the eyepiece is not merely apparent, but a real physical one.

M-16

Our exploration of this stellar wonderland continues with an object having a dual nature: that of a diffuse nebula and an involved open star cluster. This is M-16 in Serpens, easily picked up in finders and binoculars about 3° west and 1° north of the star Gamma (γ) Scuti, near the intersection of the borders of Serpens, Scutum, and Sagittarius.

The cluster part of M-16 contains over 50 member suns scattered over an area 25 to 30 minutes across (or nearly the apparent size of the full moon) and shines with the combined light of a 6th magnitude star. The nebulosity itself has a low surface brightness and requires medium to large-sized (8"-12") telescopes to be seen well. Slow sweeping back and forth across this object with a 4-inch at 45x to 90x will show the cluster members to be enveloped in a very faint cosmic mist or fog. As Burnham points out, the glowing nebulosity is "quite evident today in a good 6-inch or 8-inch telescope." Whatever instrument is used, a dark (moonless) transparent night and the use of averted vision help greatly in glimpsing its ghostly presence.

M-16 is often called the "Eagle" or "Swan" Nebula because of its likeness to these birds created by the dramatic "fingers" of dark gas and dust seen projected against the bright nebular background in time-exposure photos. Burnham, pointing out that both these birds are already honored in the sky by Aquila and Cygnus, suggests a different name here — that of the "Star Queen" Nebula. Careful scrutiny of any observatory rendering of this object will show this to be a strikingly appropriate analogy, and hopefully it will catch on as well as the other two have.

Webb tersely described M-16 as a "grand cluster," but like many other early observers made no mention of the involved nebulosity. Even some modern descriptions fail to point out its presence. Messier authority Holyoke calls this object a "nice, easily resolved cluster — 60x on any telescope will give a good view," and Muirden mentions a "hexagonal cluster of bright stars and star dust" — both failing to indicate to their readers that there is a nebula here.

Selected Objects — Serpens Cauda/Scutum

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.
Nu (ν) Ser	$\star^2$	4.4,8.7	46"	17^h18^m	-12°48'
*M-16	□,○	6.4	25'	18^h16^m	-13°48'
Σ 2306	$\star^2$	7.2,7.9	10"	18^h19^m	-15°07'
59 Ser	∩★,$\star^2$	4.9-5.9,7.8	4"	18^h25^m	+00°10'
NGC-6645	○	8.5	10'	18^h30^m	-16°56'
*M-26	○	9.3	9'	18^h42^m	-09°27'
R Sct	ᗰ★	4.9-8.2	140^d	18^h45^m	-05°46'
*M-11	○	6.3	10'	18^h48^m	-06°20'
NGC-6712	●	8.9	2'	18^h50^m	-08°47'
*Theta (θ) Ser	$\star^2$	4.6,5.0	22"	18^h54^m	+04°08'

*Detailed in Close-Up

★ *Star*
$\star^1$ *Bright Star*
$\star^2$ *Double Star*
$\star^3$ *Triple Star*
ᗰ★ *Regular Variable*
∩★ *Irregular Variable*
Ӿ★ *Eclipsing Variable*
○ *Open Cluster*
● *Globular Cluster*
■ *Planetary Nebula*
□ *Bright Diffuse Nebula*
§0 *Elliptical Galaxy*
§S *Spiral Galaxy*
§∫ *Barred Spiral Galaxy*
§# *Peculiar/Irregular Galaxy*

The NGC calls M-16 a cluster and mentions the presence of at least a hundred bright and faint stars here, but says nothing of the nebula itself. Mallas, on the other hand, working with a small telescope, apparently glimpsed it easily. His account states: "One of the most unusual objects in the sky and a fine sight at low power. The 4-inch [refractor] reveals three nebulous regions and about 20 stars against an uneven background."

The most inspired and exciting account of M-16 has to be that of Burnham, who calls this object "one of the great masterworks of the heavens" and a "large scattered star cluster immersed in a vast diffuse nebula, a most wonderful object whose full glory is only revealed on long-exposure photographs."

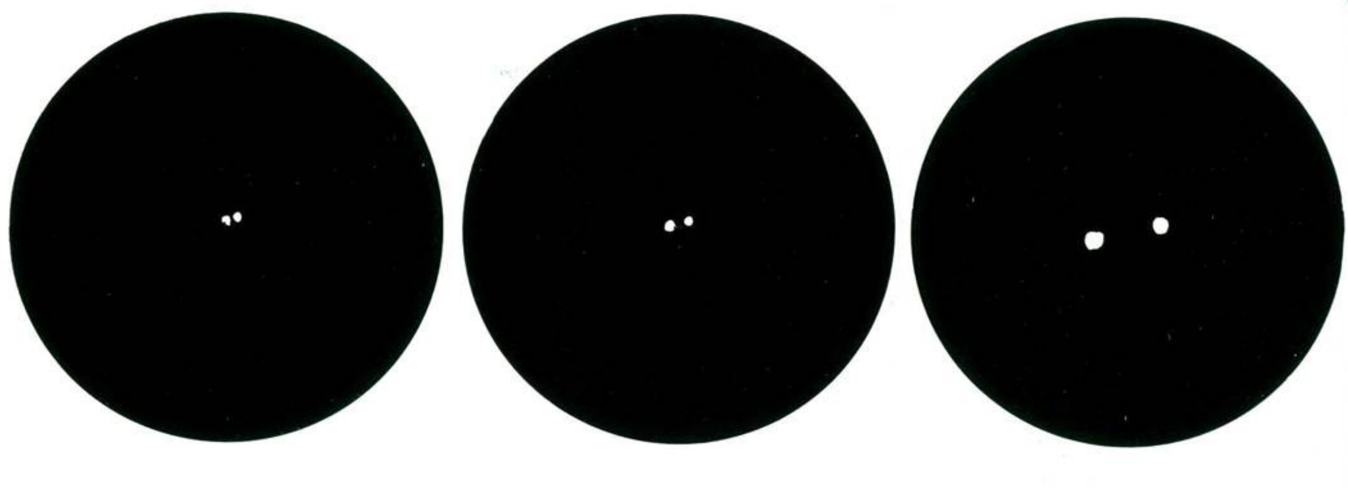
Yes, something very exciting is happening here, for M-16 is one of the most active sites of star (and planet?) formation in the sky. It seems that Burnham's "Star Queen" is also a mother, keeping watch over her stellar nursery from atop her star-studded throne. We are watching this awe-inspiring cosmic spectacle across some 8,000 light-years of space and time.

M-11

Saving the best for last, we conclude this month's celestial sightseeing tour with a glittering stellar jewel box that ranks as perhaps the finest open star cluster visible from northern latitudes. This is M-11 in Scutum, just visible to the unaided eye on a dark night as a misty 6th magnitude glow west of the star chain formed by Lambda (λ) Aquilae, 12 Aquilae and Eta (η) Scuti (or 4° southwest of Lambda itself).

M-11 is a glorious sight in any size telescope from the smallest to the largest. It is one of the few bright members of its class that is rich and compact enough to remain striking in observatory instruments, with their typically high minimum magnifications and reduced fields of view. Medium powers seem to work best — 90 diameters on a 4-inch glass breaks this object into a beautiful splash of star dust, while the view in 8 to 12-inch apertures is simply breathtaking.

This object appears as a very rich and uniformly bright swarm of more than 200 suns in an area at least 10 minutes of arc in extent on the sky. (Actual cluster membership is estimated at 500 to 600 stars down to the limit of a 10-inch telescope.) Its outline is somewhat triangular and there is a relatively bright star near its apparent center. Most published



Above: The double star Theta (θ) Serpentis is easily split by 10 x 50 binoculars, but small telescopes provide a better separation of the two nearly identical components. Drawings by James Mullaney. Right: The open cluster M-16, together with its associated nebulosity, is one of the most beautiful sights in the heavens. The "Eagle" is its most familiar name, but M-16 is also called the "Swan" and the "Star Queen." Photo by Jack Newton.

accounts of M-11 call it "fan-shaped" and Admiral Smyth long ago likened its appearance to a "flight of wild ducks" — both analogies fit this clan perfectly, as you can see for yourself the next clear night.

M-11 is considered something of an oddball among the family of star clusters. It looks too rich and concentrated for a normal open cluster but too sparse and unsymmetrical to be a globular. Thus, it is sometimes labeled a "semi-globular". Short exposure photos show it as an open cluster, but on long ones it looks very much like a typical globular. Recording the changing aspect of this strange grouping with increasing exposure time would be an interesting and informative project for any astrophotographer.

D'Arrest called M-11 "a magnificent pile of innumerable stars...irregular and as if divided into several agglomerations." Chambers considered it an "exceedingly beautiful aggregation of small stars of about 11th magnitude," while Norton described it as "a grand, fan-shaped cluster, with bright star at apex. Dark structures to the south." Bernhard, Bennett, and Rice gave it as "semiglobular" in form. Holyoke saw it as a "perfectly exquisite little open cluster" and Brown in part said it is "a real sparkler!"

Webb's account of M-11 points out similar features here of interest to the visual observer: "Noble fan-shaped cluster, stars 11th magnitude divided into 5 or 6 groups, noted independently with 5.5-inch [refractor]. An 8th magnitude star is a little within its apex; an open 8th magnitude pair south following [east] beyond it — Ellison notes 'dark structures' plainly visible."

The dark structures mentioned in the above accounts have been reported by some visual observers, appearing as lanes or rifts crossing M-11 and apparently devoid of stars. These may be an illusion arising from a random stellar distribution and star chains within the cluster, or they may be real filaments of obscuring interstellar dust seen projected against this mass of stars. In any case, they appear even in a 3 or 4-inch telescope, while in 10 and 12-inch apertures they look distinctly darker than the softly glowing sky background outside the cluster itself.

Bright nuclear stars, star chains, and dark lanes in M-11 and other clusters are a frequent sight to the attentive visual observer. Unfortunately, they have received little notice by professional astronomers — probably because such features are lost on lengthy time-exposure observatory photos or lie hidden in photometric printouts.

Muirden's description of M-11 reads: "the Wild Duck cluster. A superb fan-shaped cluster, granular with stars, with a 9th-magnitude star at the apex and a small double to the north. The surrounding region glitters with faint stars." The small double is the same one mentioned above and lies southeast rather than north of the cluster. Pickering again mystifies us, for he included this object as only a runner-up to his roster — a fact difficult to understand since it clearly equals or excels any of the other clusters on his primary list.

A final impression is that of Burnham, whose lengthy description reads in part: "Exceptionally fine galactic star cluster, lying on the north edge of the prominent Scutum star cloud, and one of the outstanding objects of its type for telescopes of moderate aperture...In binoculars or a low power telescope it at first resembles a globular, but with increasing magnification the stars begin to draw apart, finally revealing M-11 as a rich swarm of glittering star points, somewhat triangular in shape with one brighter star near the center, but no real central nucleus."

Informative as accounts like the foregoing may be to the reader, they are but the secondhand narrative of the cosmic traveler. To fully sense the visual impact and ethereal beauty of celestial glories like M-11, you must go directly to the eyepiece yourself and experience them firsthand. Only then does the meaning of the following closing lines from a poem written by Haji-el-Nujum, himself a "Pilgrim of the Stars" come clear:

"Lo, the Star-Lords are assembling,
And the banquet-board is set;
We approach with fear and trembling,
But we leave them with regret."

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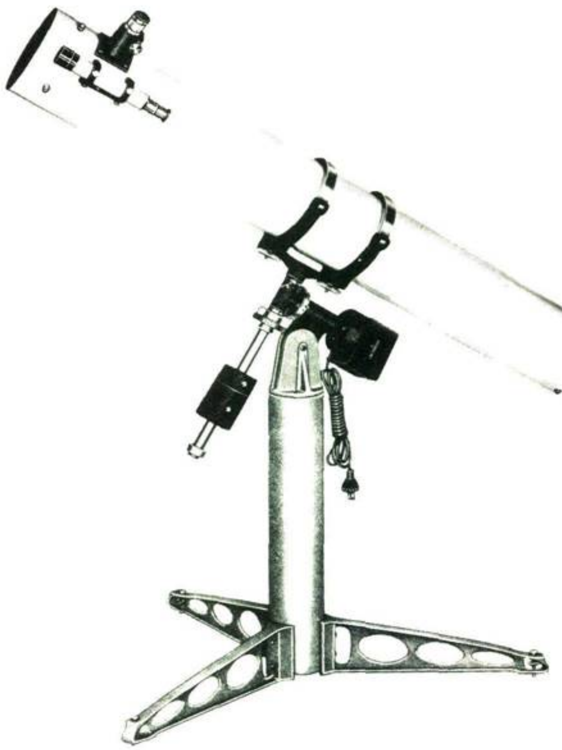

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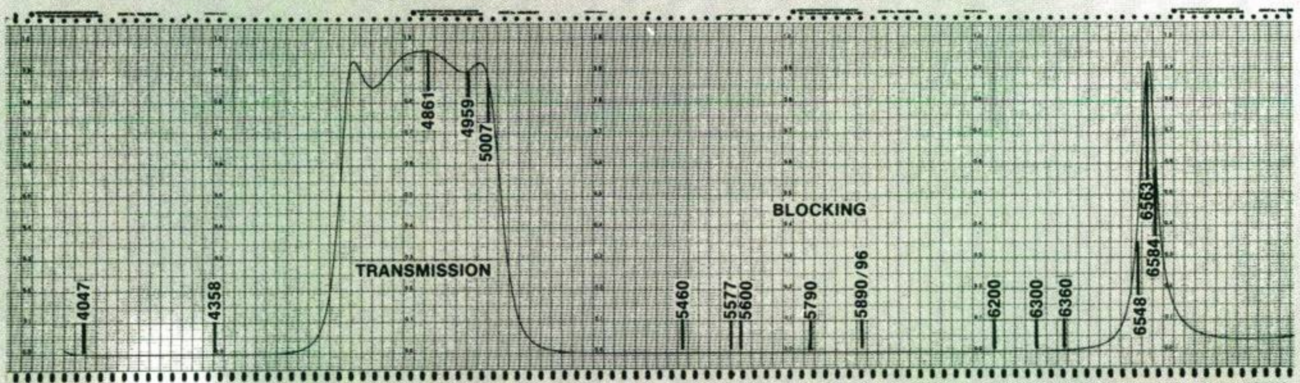

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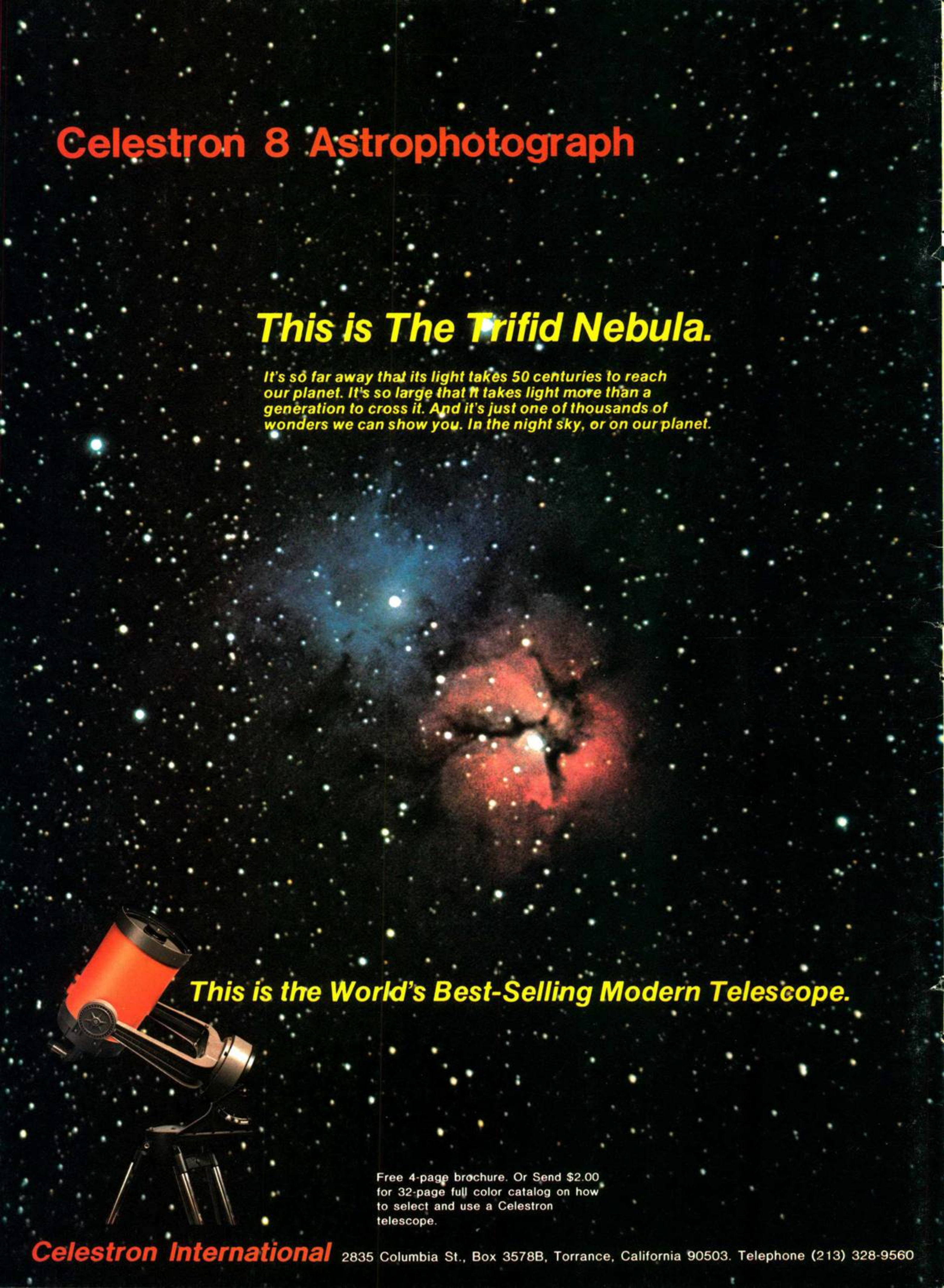

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